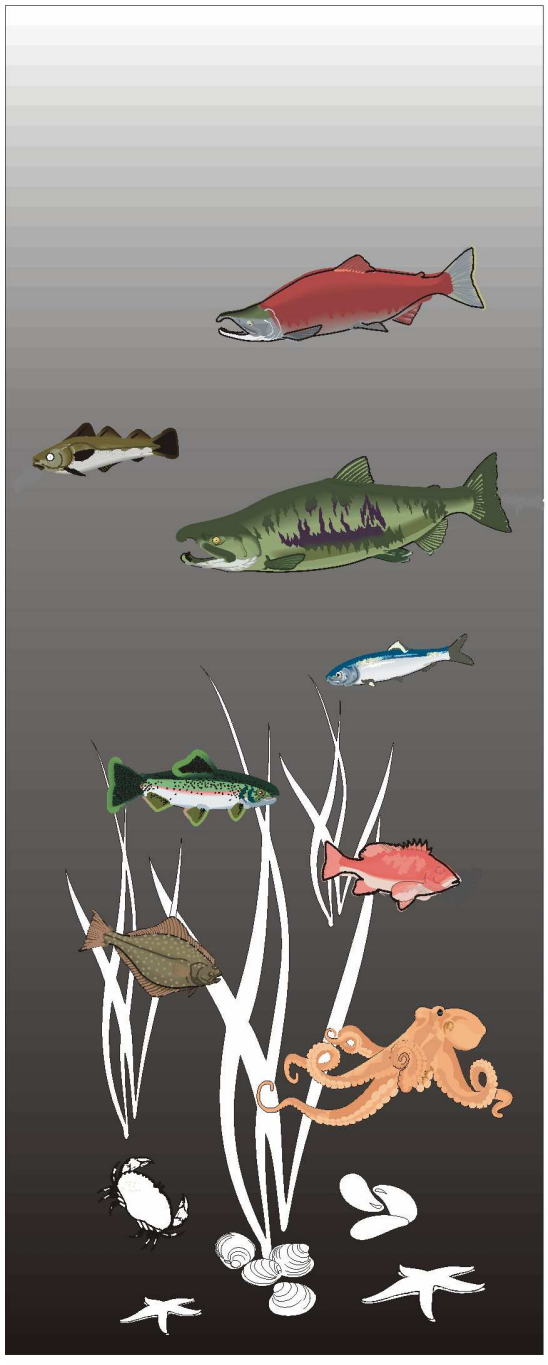
Northwest Fishery Resource Bulletin



Coho Salmon Escapement to the Skagit River Estimated Using a Mark-Recapture Method: 1986

By

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Project Report Series No. 6

Northwest Fishery Resource Bulletin

Project Report Series

The Northwest Fishery Resource Bulletin presents the results of investigations carried out by the Washington Dept. of Fish and Wildlife, Western Washington Treaty Tribes, and/or the Northwest Indian Fisheries Commission that are deemed of sufficient interest to be made available to the scientific community and the public.

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ABSTRACT

Since 1965, an index live-count method has been used to annually estimate the number of coho salmon in the escapement to the Skagit River. The accuracy and precision of the estimates from this method have never been critically examined. A 5-year project to examine alternative methods of estimating the number of wild coho salmon in the escapement to the Skagit River began in 1986. In addition to the index live-count method, three other methods of estimating the coho salmon escapement to the Skagit River were examined: (1) a mark-recapture method; (2) a redd-count expansion method; and (3) a method based on estimates of the proportional contribution of hatchery-produced coho salmon to the total escapement. **This report documents the results of the mark-recapture portion of the project for 1986.**

In 1986, coho salmon were captured with a beach seine between river miles 32 and 38 of the Skagit River from 15 September through 14 November. A total of 1,689 coho salmon were tagged with a jaw tag and marked with an operculum punch. Tags were recovered during surveys designed to randomly sample the coho salmon escapement. Samples were collected at 13 areas in the Skagit River drainage: Marblemount Hatchery; Baker River trap; spawning grounds in the Middle Skagit, Upper Skagit, Lower Sauk, Middle Sauk, Upper Sauk, Suiattle, Cascade, Nookachamps, and Carpenter sub-basins; and in commercial and test fisheries. A total of 35,953 coho salmon were examined of which 35,042 fish were considered in-sample and 911 were not considered part of the population subject to tagging.

A total of 310 tagged or marked coho salmon were recovered during in-sample surveys. The tag recovery data indicated that approximately 1% of the coho salmon migrating through the tagging area in the lower Skagit River were caught and tagged. The percentage of tagged or marked coho salmon in the samples from nearly all the major recovery areas (areas with seven or more tag recoveries) was near 1%: Marblemount Hatchery 1.1%; Baker River trap 1.0%; commercial fishery 1.0%; Middle Skagit sub-basin 0.9%; Lower Sauk sub-basin 0.9%; and Suiattle sub-basin 0.8%. The one exception was the Middle Sauk sub-basin sample where only 0.4% of the fish examined were tagged or marked. The tag recovery data indicate that some coho salmon from spawning areas substantially downstream of the tagging site were present in the tagging area. There were two tags recovered in 411 coho salmon examined (0.5%) during spawning ground surveys in the Nookachamps and Carpenter sub-basins.

The estimated abundance of coho salmon in 1986 was 161,926 fish with a 95% confidence interval of 143,082 to 188,325 fish. This estimate is for the number of coho salmon migrating through the tagging area after tagging began on 15 September. It includes all coho salmon bound for spawning areas above the tagging area and an unknown fraction of the salmon from spawning areas in the Nookachamps and Carpenter sub-basins. This abundance estimate was very precise (CV = 6.5%) because of the large number of fish examined for tags during in-sample surveys. To restrict the estimate to spawning areas in the Middle Skagit sub-basin and spawning areas above it, adjustments were made to the number of tags released. Using the adjusted number of tags released, the estimated abundance for this more restricted area was 155,889 coho salmon. **The total return of coho salmon to Skagit Bay in 1986 is estimated to be 187,525 fish. There were an estimated 139,153 naturally-spawning coho salmon in the escapement to Skagit River spawning grounds**: 127,750 fish were estimated to have reached upstream spawning grounds and 11,403 coho salmon were estimated for lower river (Nookachamps and Carpenter sub-basins) spawning grounds (see summary table on the next page).

Table summarizing the total return of coho salmon to Skagit Bay in 1986 by major components.

Component	Number of Fish
Total Terminal Run Size	187,525
Marblemount Hatchery	12,970
Baker River Hatchery	2,322
Commercial Fishery Catches	29,876
Test Fishery Catches	3,204
Subtotal	48,372
Wild Escapement	
Upstream Areas	127,750
Lower Areas	11,403
Subtotal	139,153
Sport Catch[a]	1,819

[a] An unknown portion of the sport catch should be subtracted from the wild escapement and the remainder added to the total terminal run size.

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INTRODUCTION

The Skagit River is the largest river system in the Puget Sound region. It has 162 miles of mainstem river and its headwaters are in Canada (Figure 1). This system is one of the largest producers of coho salmon (*Oncorhynchus kisutch*) in northern Puget Sound. Coho salmon from the Skagit River are caught in fisheries from Northern California to Southeast Alaska and are a major contributor to fisheries in the inside marine waters of Georgia Strait and Puget Sound (PFMC 1992). The Skagit River is managed for natural production of coho salmon (subsequently referred to as wild coho salmon). In years when the numbers of wild coho salmon projected to return to the Skagit River are small, fisheries from Cape Falcon, Oregon to the US/Canada border have been constrained to protect these fish (PFMC 1986, pg. III-9; and PFMC 1988, pg. III-11). Accurate annual assessments of stock status are required for coho salmon from the Skagit River because this stock can affect the management of fisheries over such a large geographic area. This ensures that fisheries are not unnecessarily restricted during years when there is not a conservation problem and prevents over-harvest of wild coho salmon from the Skagit River during years of small returns. An important component of the information needed to accurately assess the status of wild coho salmon from the Skagit River is an annual estimate of the number of coho salmon in the spawning escapement. Spawning escapement, as used in this report, refers to the number of adult coho salmon which are present in all natural spawning areas of the Skagit River and have the potential to spawn in these areas. It does not include coho salmon returning to Marblemount Hatchery or to the release site for hatchery-produced coho salmon at the Baker River dam.

Since 1965, the Washington Department of Fish and Wildlife (WDFW) has used an index live-count method to annually estimate the escapement of coho salmon to the Skagit River (Flint 1983). The accuracy and precision of the estimates from this method have not been critically examined. A five-year project to examine alternative methods of estimating the number of wild coho salmon in the spawning escapement to the Skagit River was begun in 1986. This project was conducted by the Skagit System Cooperative (SSC) in cooperation with personnel from WDFW and Puget Power and Light. Three methods of estimating the spawning escapement of coho salmon to the Skagit River were examined: (1) a mark-recapture method; (2) a redd-count method; and (3) a method based on estimates of the proportional contribution of hatchery-produced coho salmon to the total escapement.

This report is the first in a series of reports that will document the studies conducted from 1986 through 1990 which examined different methods for estimating the escapement of coho salmon to the Skagit River. **This report summarizes the data and documents the results of the mark-recapture portion of the project for <u>1986</u>.** Reports documenting the results for the other years that tagging was conducted (1987, 1988, 1989, and 1990) and the other methods of estimation will follow. Some summary data from these other years of the study are presented in this report as these data support some of the assumptions required for the analysis of the tagging data from 1986.

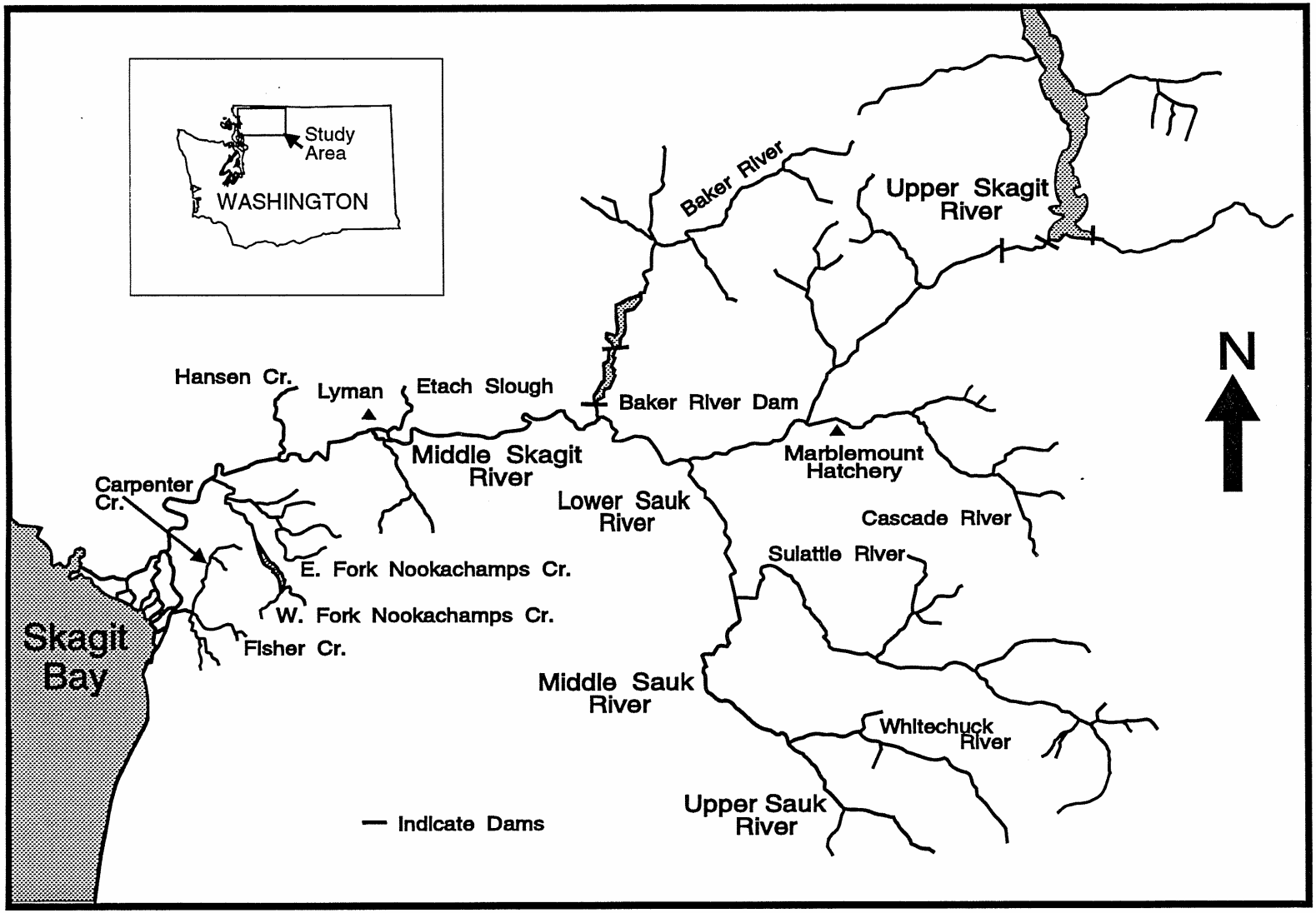

Figure 1. Map of the Skagit River system showing the location of the areas where tag recovery surveys were conducted.

METHODS

The description of methods is divided into five sections. The first section describes the methods used to capture coho salmon for tagging and the tagging procedures. The next section describes the surveys used to recover tags. This includes a description of the survey procedures for each of the tag recovery areas. Section three describes the statistical procedures used to estimate the abundance of coho salmon from the tag release-and-recovery data. The fourth section describes studies designed to estimate mortality due to tagging that were conducted during the five years of the study. The last section describes some miscellaneous analyses conducted to examine migration timing and the sex and length composition of the coho salmon that were sampled.

Tagging Methods

Beach Seining:

Coho salmon were captured for tagging using a beach seine operated by a five-man crew. Seining was conducted at nine sites in an area between river mile (RM) 32 and RM 38 of the Skagit River (Figure 2). A 3″-mesh, monofilament beach seine that was 240′ long by 20′ deep was used to capture coho salmon. The net had a 36′ bunt made of 2″ knotless seine material. Cork spacing was 8″ on the bunt and two feet on the rest of the net; the leadline was hung with 15 lb per 60′ of net. Modifications in net dimensions occurred whenever the seine was damaged. Due to heavy use, the leadline was rehung about every four fishing days and the monofilament was replaced after every eight to ten fishing days.

A boat was used to set the beach seine. One end of the seine was held by two crew members on a gravel bar while the boat backed away from the shore and the net was set off the bow of the boat. When the entire net was out, the boat-end of the net was towed downstream. The other end of the net was attached to a four-wheel drive truck and driven slowly downstream. Care was taken to prevent the shore-end of the net from getting ahead of the boat because fish tended to lead away from the shore and around the boat. During the drift, a seine plunger (a long pole with a cup on the end) was slammed into the water periodically to drive fish away from the river-end of the net and toward the shore. At a pre-designated point the boat returned to the gravel bar. Upon reaching the shore, the boat-end of the net was attached to the back of a second four-wheel drive truck. Both trucks then pulled the net up the gravel bar, perpendicular to the river, until only the bunt end of the net was in the water. The five-man crew then pulled the bunt in by hand until the leadline was on shore while the cork line and ends were cradled by the crew.

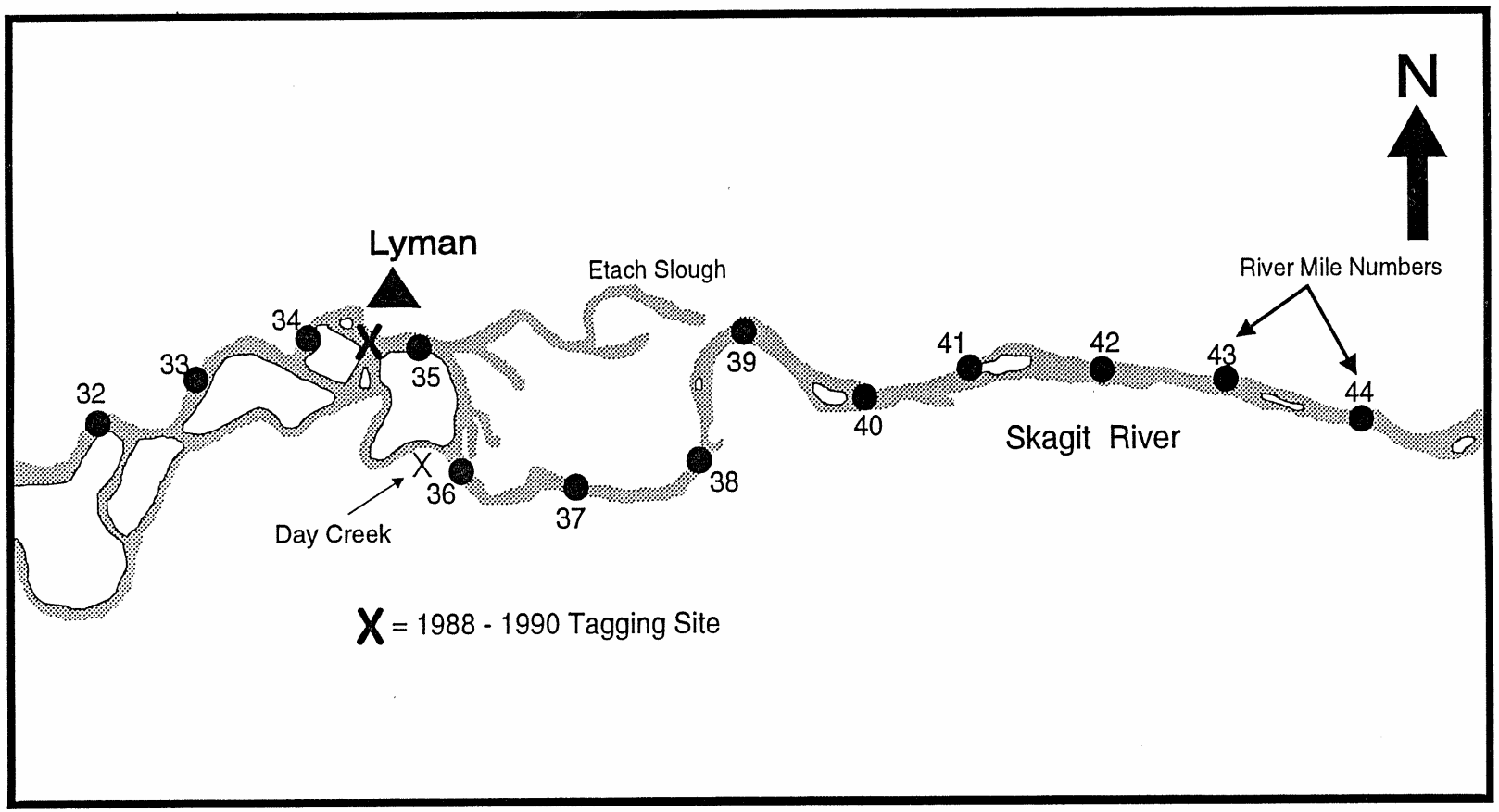

Figure 2. Map of the area of the Skagit River where coho salmon were captured and tagged, 1986-1990.

Tagging Procedures:

Coho salmon were removed from the bunt and placed into either of two net pens adjacent to the capture site. All other species were counted and returned to the river. The pens were 3′ by 5′ by 5′, constructed of PVC, and covered with 0.5″ knotless nylon mesh. Each coho salmon was taken from a net pen by a sampler wearing cotton gloves and placed on a V-shaped measuring board lined with high-density foam. A sequentially-numbered hog ring[1] was clamped around the lower left mandible of each fish using a pair of hog-ring pliers and a 3/8″ hole was punched in the rear center of each gill operculum with a paper hole-puncher. The fork length (measured to the nearest cm), sex of the fish, any external marks, and a qualitative assessment of maturity (bright, blush, or dark) were recorded for each fish with the date and tag number. Each tagged salmon was held gently in the water until its equilibrium was regained before being released. If a tagged fish did not swim away or appeared to be injured it was given a condition rating of "X-". Fish that swam away normally were given a condition rating of "X". If a fish was especially vigorous when released a condition rating of "X+" was assigned. Fish with severe physical impairments (e.g., 50% scale loss, torn opercula, deep predator wounds) were released untagged. These included jack coho salmon (male salmon under 30 cm in length) which generally gilled in the net and were unfit for tagging.

Tag Recovery Surveys

Only tags recovered during surveys designed to randomly sample the coho salmon escapement were used for the abundance estimates. These are referred to as **in-sample recoveries**. Tag recovery surveys were conducted by sampling: (1) all fish spawned, surplused, or otherwise sacrificed at Marblemount Hatchery; (2) all fish caught at the fish trap at Baker River dam; (3) the catch by the in-river commercial fishery; (4) all test fishery catches; (5) every reachable and identifiable dead coho salmon found during spawning grounds surveys; and (6) every coho salmon caught in traps operated on Fisher Creek (a tributary to Carpenter Creek) and Hansen Creek (a tributary to the Middle Skagit sub-basin). During each survey or day of trap operation, the date, number of coho salmon inspected for tags, number of tagged or marked (with the opercula punches) fish found, and tag numbers of all coho salmon recovered with legible jaw tags were recorded.

Marblemount Hatchery:

Samples were collected by three different methods at WDFW's Marblemount Hatchery: spawned fish, surplused fish, and pond mortalities. After any processing, hatchery personnel sorted the fish from these groups into separate bins for tagged/marked and unmarked fish. SSC crews then re-checked these bins for coho salmon with tags or marks. The date of sampling, number of coho salmon inspected for tags, number of tagged or marked fish found, and tag numbers of all coho salmon recovered with legible jaw tags were recorded.

[1] Aluminum bird bands were placed on 139 coho salmon.

Coho salmon were spawned at Marblemount Hatchery to meet specific egg-take goals. Spawning was conducted when the portion of the run from which eggs were desired was present and there were large numbers of fish in the holding ponds. Hatchery personnel selected fish for spawning and sorted them into the bins after spawning for SSC crews to examine. Surplused fish were those in excess of the spawners needed for eggs. Surplus coho salmon were periodically sacrificed and sorted into the bins. The holding pond was periodically surveyed for mortalities and any dead coho salmon were removed and sorted into the bins. A schematic of the Marblemount Hatchery sampling procedure is shown in Figure 3.

Except for the pond mortalities, hatchery personnel selected the coho salmon for the other two groups, spawned and surplused, according to a visual assessment of the fish and the timing of the return to Marblemount Hatchery. Therefore, these fish were not strictly sampled at random and the percentage of tagged fish in these samples might have been influenced by the selection process. However, since all coho salmon returning to the hatchery were sampled, the Marblemount Hatchery sample was a census and the sample total for the entire spawning season provided the best estimate of the percentage of tagged coho salmon at Marblemount Hatchery.

Baker River Trap:

A fish trap at Baker River dam caught all upstream migrating salmon. All coho salmon caught at the trap were examined. Fish caught in the trap were crowded into a brail and several removed at a time onto a sorting table. Each coho salmon was examined for a tag or mark. The sample date, condition, and tag number (when legible) were recorded for any jaw-tagged or opercula-punched coho salmon. After all live fish in the brail were removed, the racks and screen of the trap were searched for dead fish. Therefore, identically to the Marblemount Hatchery sample, the Baker River trap sample was a census and the sample total for the entire spawning season provided the best estimate of the percentage of tagged coho salmon at the Baker River trap.

The Baker River stock is one of the earliest returning coho salmon stocks to the Skagit River. Coho salmon were counted at the Baker River trap before tagging began in the lower river during two years of the study. In the other years of the study, coho salmon were counted at the trap so soon after tagging was initiated that we assumed some fish had migrated past the tagging site before tagging had begun and, therefore, were not subject to capture. Since these early-arriving fish were not subject to tagging, we excluded them from the number of fish examined for tags that was used for the population estimates (i.e., they were not considered in-sample). We examined the number of days between release and recapture for all coho salmon recovered at the Baker River trap during the five years of tagging. The minimum travel time (number of days between being tagged and released in the lower river and recovered at Baker River trap) during the study years was used to determine which of early-arriving fish should be excluded from the in-sample survey (census) at Baker River trap. To be consistent, this overall minimum travel time was used in all five years of the study.

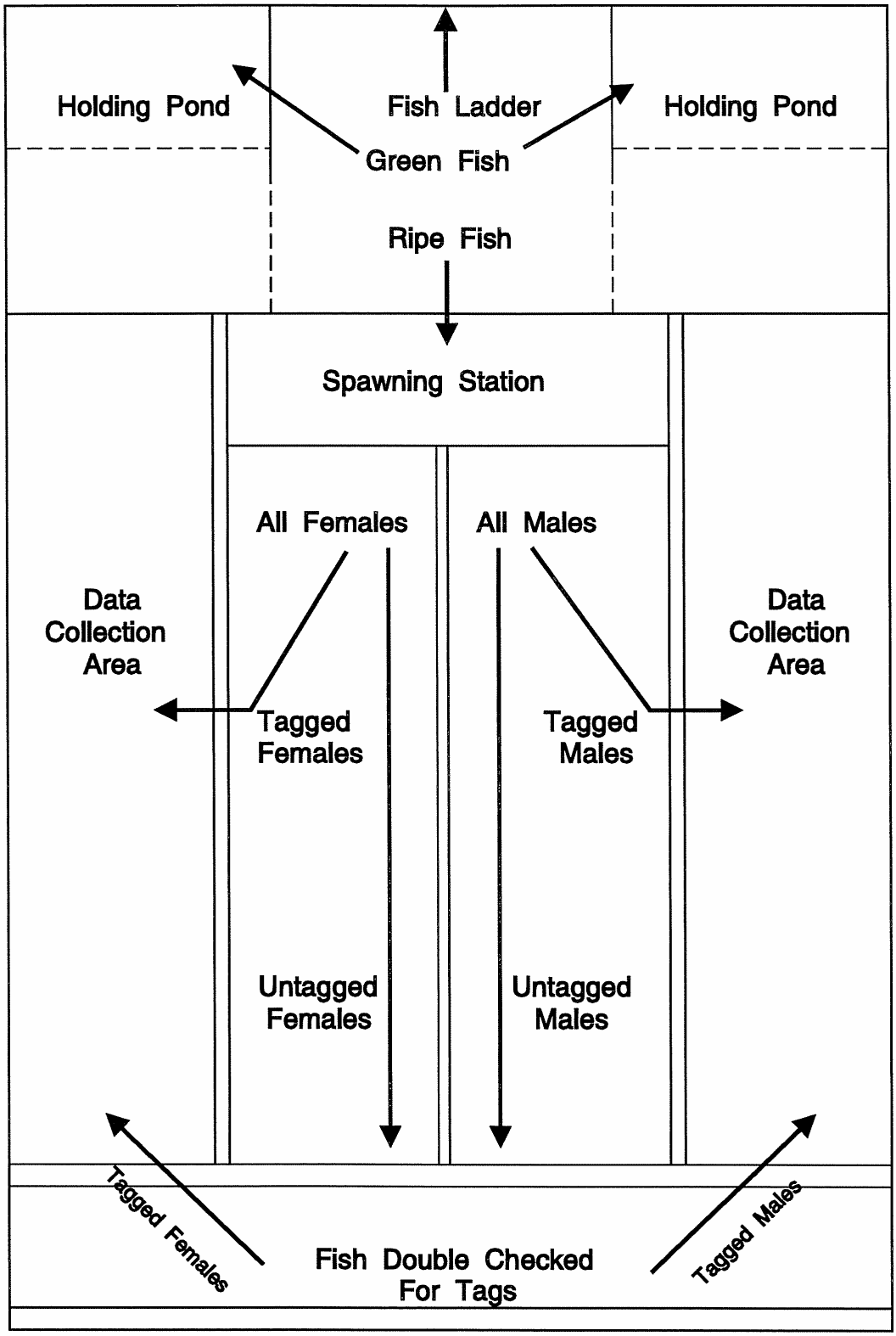

Figure 3. Schematic of the sampling procedure used to process coho salmon for tag examination at Marblemount Hatchery.

In-River Commercial and Test Fisheries:

Tag recovery samples from the commercial catch were collected in conjunction with routine commercial catch sampling activities. The Skagit River is divided into statistical areas for commercial catch regulation (Figure 4). To allow tag recovery samples from the catch to be analyzed by area of capture, all major salmon buyers were instructed to place catches from each statistical area into separate bins. This occurred during the fishery for chum salmon and the early part of the fishery for steelhead in the Upper Skagit River. In 1986, samples were not allocated to the sub-areas (78D-2, 78D-3, etc.) within Area 78D so we assumed that all samples were collected from the upstream areas (78D-3 or 78D-4) for the population analyses. Incidental catches of coho salmon during the later part of the steelhead fishery in the Upper Skagit River were not sorted by area.

A test fishery was conducted each year by an SSC crew to provide an in-season assessment of the size of the coho salmon run. In 1986, test fisheries were conducted in: Areas 2, 3, and 4; and at Blakes; Jetty (in Skagit Bay); and Spudhouse (Figure 4). Drift and set gill nets used at the test fish sites had mesh sizes ranging from 5″ to 6″. Hayman (1996) describes the test fishing procedures in detail. All coho salmon caught during the test fishery were inspected for tags or marks.

Both WDFW and tribal commercial catch and hatchery samplers in areas outside of the Skagit River were notified to look for jaw tags from the Skagit River study. These recoveries allowed us to assess the degree of out-of-system straying for coho salmon tagged in the mainstem of the Skagit River.

Spawning Grounds:

Tag recovery surveys of the spawning grounds were conducted in conjunction with surveys to estimate the coho salmon escapement using redd counts (Conrad et al. 1993). For the redd-count method, the Skagit River system was stratified into the nine sub-basins listed by Johnson (1986): Carpenter; Nookachamps; Middle Skagit; Upper Skagit; Lower Sauk; Middle Sauk; Upper Sauk; Suiattle; and Cascade (Figure 1). Stream sections in each sub-basin were surveyed from one to 23 times during the spawning period for coho salmon. In 1986, about 43% of the total length of potential spawning habitat in the Skagit River was surveyed (Conrad et al. 1993). During spawning ground surveys, any coho salmon carcasses observed were sampled for jaw tags and opercula marks. Gill opercula of untagged carcasses were carefully inspected for marks or healed marks. A healed (regenerated) mark was evident as a perfectly round discoloration on the gill cover that was lighter in color than the surrounding opercular tissue. Occasionally a carcass could not be sampled because of a missing head due to advanced decomposition or removal by predators. Unsampled carcasses were tallied during each survey. The date, survey location, number of coho salmon carcasses sampled, number of tagged or marked fish recovered, and tag numbers of all coho salmon recovered with legible jaw tags were recorded during these surveys. The caudal fin of all sampled carcasses was removed to prevent the carcass from being sampled again during subsequent surveys.

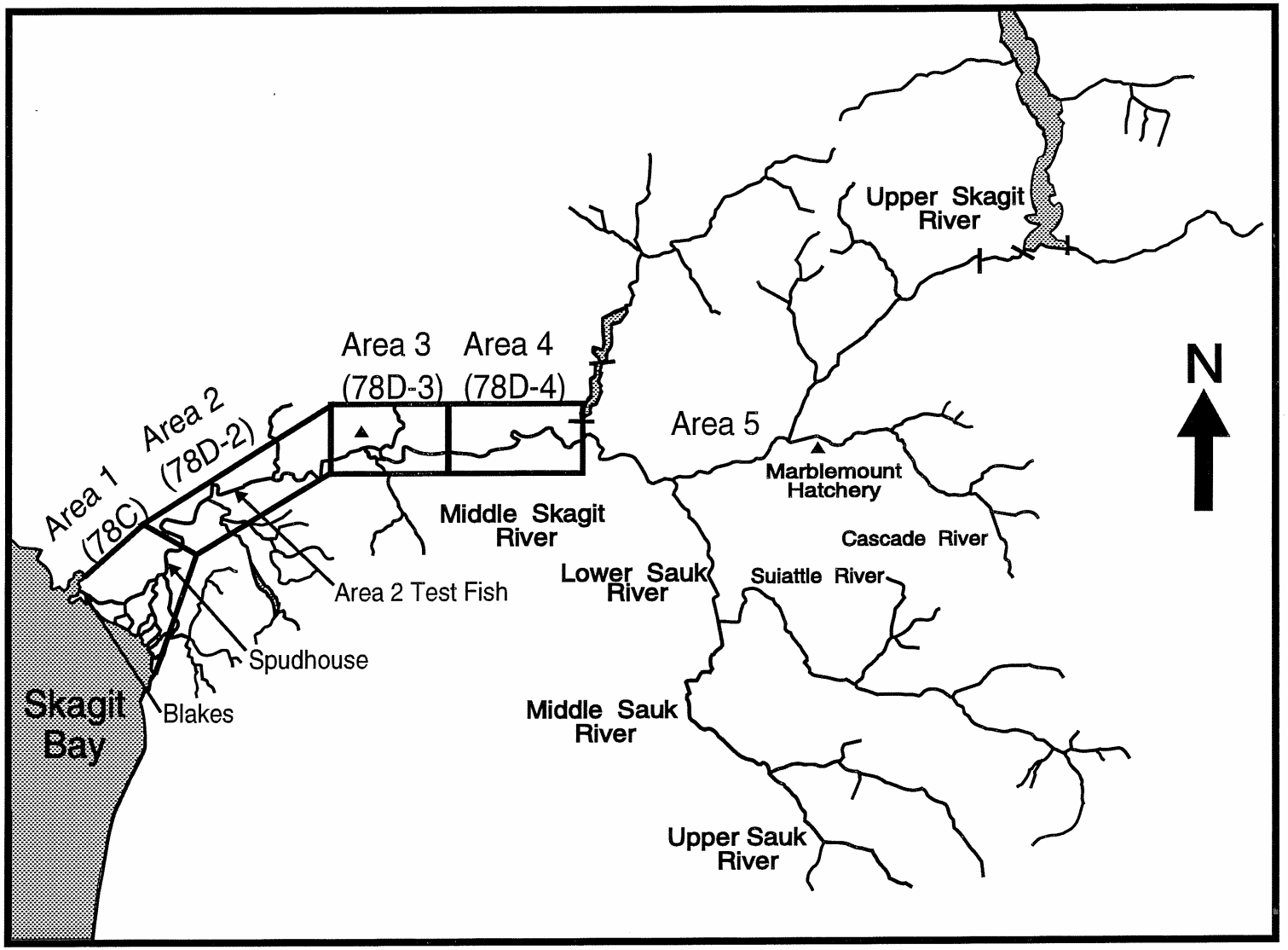

Figure 4. Commercial fishery areas of the Skagit River as designated by WDFW.

Tributary Traps:

SSC operated two fish traps in 1986. One was on Fisher Creek, a tributary to Carpenter Creek, and the other was on Hansen Creek, a tributary to the Middle Skagit River (Figure 1). These traps were located in areas that had easy accessibility, a section of relatively straight stream channel with a low gradient, and a stable substrate. Both traps were wooden weirs that blocked the entire creek and funneled fish into a live box.

All traps were checked and cleaned at least twice daily. A knotless-nylon dip net was used to move the trapped coho salmon into a 30-gallon plastic container filled with water. All coho salmon caught were examined for tags or marks and then released upstream. A Petersen disk tag and a unique operculum punch (i.e., a punch pattern different from that used in the main-river tagging) were placed on all coho salmon released above the traps. The trap crews also recovered tags at the weirs from spawned-out carcasses which had washed downstream from the spawning areas (called rack recoveries). The caudal fin was cut off all rack recoveries. The date, number of coho salmon sampled, number of tagged or marked fish recovered, and tag numbers of all coho salmon recovered with legible jaw tags were recorded.

Abundance Estimates

Two different mark-recapture models were used to estimate the number of coho salmon passing through the tagging area in the lower Skagit River, the Petersen estimation model and Darroch's stratified estimation model. When tagging and recovery occur over an extended time period, such as occurred in this study, it is not uncommon to observe temporal changes in: (1) the probability of capture of fish in the target population; and/or (2) the probability of finding a tagged fish during tag recovery surveys. When such changes occur the Petersen model is often not the appropriate estimation model. Seber (1982) describes a series of χ^2 tests to determine whether the data are consistent with a Petersen estimate. Specifically, the tests determine whether the data are consistent with the following four conditions: (1) there was uniform recovery of tags across the tag recovery strata; (2) there was uniform tagging across the tag release strata; (3) there was complete mixing of the population between tagging and recovery; and (4) the expected number of tags recovered in each stratum was proportional to the number of unmarked individuals present.

Eames et al. (1981, 1983) describe the exact form of these tests for a study similar to ours in both the study design and estimation procedures. They captured chum and coho salmon in marine areas immediately in front of the mouths of major river systems in Puget Sound and tagged the fish with jaw tags. Tags were recovered during surveys of spawning grounds throughout these river systems. We followed procedures similar to those described by Eames et al. (1981, 1983) to determine the appropriate estimation model.

Petersen Estimation Model:

The simplest and most commonly used model for estimating abundance from mark-recapture data is the Petersen model. Six basic assumptions of the Petersen model are (Seber 1982):

1. The population is closed. There is no immigration, emigration, recruitment, or death of animals during the mark-recapture experiment.

2. All animals in the population have an equal probability of capture during the first (tagging) sample.

3. The second (recovery) sample is a simple random sample of the population.

4. Tagging does not affect the catchability of an animal.

5. Animals do not lose their tags between the first (tagging) sample and second (recovery) sample and there is no tagging-induced mortality.

6. All tagged animals are reported (recognized) in the second sample.

The first assumption can be liberalized by specifying the point in time (or space) the population estimate applies. Permanent emigration can be viewed as a process identical to death since both effectively remove animals from the population. Similarly, recruitment and immigration can be considered identical processes since both add animals not subject to tagging to the population. Therefore, emigration can be substituted for mortality and immigration can be substituted for recruitment in alternate assumptions 1a and 1b below (Seber 1982):

1a. There is mortality, but no recruitment, and the mortality is a simple random process with an equal probability of death for all animals in the population. The estimate is for the population size at the time of the first (tagging) sample.

1b. If there is recruitment into the population, but no mortality, then a Petersen estimate is a valid estimate of the population size at the time of the second (recovery) sample.

The Petersen model can be used to estimate the size of an open population if assumption 1a or 1b is met in addition to assumptions 2-6. If different capture methods are used for the tagging and recovery samples, or more specifically if the sources of selectivity of the two samples are independent, then assumptions 2 or 3 can be violated under special circumstances (Seber 1982). If the first (tagging) sample is a simple random sample of the population (assumption 2 true) then the second (recovery) sample can be highly selective (non-random), provided the selectivity is independent of mark status (assumption 4 true). Conversely, the initial capture sample can be selective (non-random) provided that assumptions 3 and 4 are true.

Robson and Regier (1964) recommend that a Petersen estimate include a minimum of seven tag recaptures to ensure that the bias of the estimate is negligible. Therefore, we estimated abundance from the tagging data only when there were at least seven recaptures of tagged or

marked coho salmon from a recovery area. When appropriate, population size was estimated using Chapman's unbiased form of the Petersen estimate (Seber 1982):

$$\hat{N} = \frac{(m+1)(c+1)}{(r+1)} - 1. \qquad [1]$$

An approximately unbiased estimate of the variance of $\hat{N}$ is (Seber 1982):

$$\hat{V}(\hat{N}) = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2(r+2)} \qquad [2]$$

where $\hat{N}$ = the estimated number of coho salmon in the population,
m = the number of coho salmon tagged and released,
c = the number of coho salmon in the second (recovery) sample examined for tags, and
r = the number of tagged (or marked) coho salmon in the second (recovery) sample.

When $\hat{\rho}$, the percentage of tagged fish in the recovery sample ($\hat{\rho}$ = r/c x 100%), was less than 10% and the number of tags recovered (r) was less than 50, a 95% confidence interval for $\hat{N}$ was estimated using the Poisson approximation and Table A1 in Seber (1982). When $\hat{\rho}$ was less than 10% and r was greater than 50, a 95% confidence interval for $\hat{\rho}$ was estimated using a normal approximation which was then inverted for a confidence interval for $\hat{N}$ (Seber 1982).

For any Petersen-type estimator (including Darroch's stratified estimator), the abundance estimate depends upon $\hat{\rho}$, the proportion of the population tagged. The proportion of tags in the second (recovery) sample provides an estimate of ρ. Generally, as ρ becomes smaller the estimated abundance becomes larger for a given number of tags released.

Darroch's Stratified Estimation Model:

Darroch (1961) developed a stratified population model for open populations that is not predicated on constant probabilities of capture or recovery. The necessary assumptions for this model are (Seber 1982):

1. All animals in the i^{th} release stratum (tagging sample) have an equal probability of capture.

2. All animals in the j^{th} recovery stratum (recovery sample), whether tagged or untagged, have an equal probability of being sampled by the recovery process.

3. Tagged animals behave independently of one another with respect to movement among strata and being recaptured.

In addition, assumptions 4-6 listed previously for the Petersen model must be satisfied.

When the number of release and recovery strata are equal the stratified estimator for open populations is (Seber 1982):

$$\underline{\hat{N}} = D_u M^{-1} \underline{a} \qquad [3]$$

where $\underline{\hat{N}}$ = a vector with the estimates of the number of untagged coho salmon in each tag release stratum just after the release of the tagged fish,

D_u = a diagonal matrix with the number of untagged coho salmon observed in each recovery stratum j,

M = a matrix of m_{ij}, the number of tagged coho salmon in each recovery stratum j, which were released in tagging stratum i, and

$\underline{a}$ = a vector with the number of tagged coho salmon released in tagging stratum i.

The estimated number of animals present in each release stratum at the time of tagging is the sum of the estimated number of untagged animals present and the number of tagged animals released in the stratum. The sum of these estimates by stratum is the total abundance estimate. The variance-covariance matrix of $\underline{\hat{N}}$ is estimated as described on pages 433-434 of Seber (1982). The variance of the total abundance estimate is the sum of the elements of the variance-covariance matrix.

If there are more release strata (i) than recovery strata (j) the stratified estimator becomes (Darroch 1961):

$$\underline{\hat{W}} = D_u \left[X D_a^{-1} M \right]^{-1} \underline{v} \qquad [4]$$

where $\underline{\hat{W}}$ = a vector with the estimates of the number of untagged coho salmon in each tag release stratum just after the release of the tagged fish,

D_u = a diagonal matrix with the number of untagged coho salmon observed in each recovery stratum j,

X = a j by i constraint matrix which specifies which release strata are to be pooled (see Seber [1982] for details),

D_a = a diagonal matrix with the number of tagged coho salmon released in tagging stratum i,

M = a matrix of m_{ij}, the number of tagged coho salmon in each recovery stratum j, which were released in tagging stratum i, and

$\underline{v}$ = a vector of length j with a zero in every position but the last element which is 1.0.

The variance-covariance matrix of $\underline{\hat{W}}$ is estimated using equations 11.20-11.23 on page 441 of Seber (1982). Total abundance and the variance of the estimated total are estimated similarly to $\underline{\hat{N}}$.

Both of Darroch's estimators (equations 3 and 4) are sensitive to the configuration of the data used in the model and can sometimes give estimates for P_j which are less than zero or greater than one[2]. This indicates that the tagging data are not meeting the assumptions necessary for the model (Seber 1982). Often this problem can be resolved by pooling appropriate data or redefining the release and/or recovery strata. If P_j was negative or greater than 1.0 in one or more of the original strata defined for a model, alternate methods of stratifying were examined. In order to pool samples for the stratified estimate, not only must the percentage of tagged fish in the samples not be significantly different, but the tag recoveries by release strata in the samples to be pooled should be proportional (Seber 1982). A χ^2 test was used to test tag recovery rates for equality and to determine if recovery strata were proportional. If more than one abundance estimate was possible from the alternate pooling strategies for a particular set of data, the estimate with the smallest coefficient of variation[3] was selected as the "best".

Definition of Strata:

Two different tag recovery percentages were examined to help define tag release and tag recovery strata. To determine if the probability of finding a tagged fish in recovery samples was different among recovery locations or among different time periods at the same location, the percentages of tags in recovery samples (ρ as defined previously) were compared. The percentages of tags recovered from releases during specific time strata, π, were compared to determine if there were differences in the probability of recovering fish tagged during different segments of the release period. For these tests it was necessary to define temporal strata for both the tag release data and the tag recovery data from each recovery area.

Tag release strata were established by dividing the release data into four to six strata with about an equal number of days of tagging in each stratum. The percentages of tagged fish recovered from the release strata (π) were tested to determine if they were equal. If a significant difference was found ($P \leq 0.10$) additional χ^2 tests were conducted to more precisely define the release strata by pooling adjacent strata which did not have significantly different π.

Three different criteria were used to establish tag recovery strata: (1) number of days of sampling; (2) number of tags recovered; and (3) number of fish examined for tags. Initially, two recovery strata were defined by dividing the data so there were approximately equal numbers of the criteria (days surveyed, number of tags, or number of fish examined) in each stratum. The percentages of tagged fish in each recovery stratum (ρ) were tested to determine if they were equal among recovery strata for each stratification criteria. If a significant difference was found ($P \leq 0.10$) additional χ^2 tests were conducted within the initially-defined strata to more precisely define the recovery strata.

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[2] P_j is the probability of an animal surviving and, if it is in the jth stratum, being caught.

[3] Coefficient of variation (CV) = $\frac{standard\ error\ of\ \hat{N}}{\hat{N}}\ x\ 100\%$.

Testing ρ and π:

Tests were conducted to determine if there were significant differences in tag recovery percentages (either ρ or π) between different samples or groups of fish (e.g., between surveys conducted by SSC and WDFW, or between samples collected during different time periods, or between samples collected at different locations, or between male and female coho salmon). When the expected number of tag recoveries for each group in a comparison was five or greater, a standard χ^2 test (Conover 1980) was used to test for differences in tag recovery percentages (ρ or π). If the number of tag recoveries was insufficient for a χ^2 test (one or more cells with expected frequencies less than five) and there were only two release strata or recovery locations to compare, Fisher's exact test (Conover 1980) was used. Otherwise, an approximate randomization test (ART) was conducted (Noreen 1989). An approximate randomization test is a computer-intensive method of testing whether the data in a contingency table are similar. It is similar to Fisher's exact test but uses a computer to repeatedly resample the data and approximately estimate the probability of observing the configuration of the data in the table (under the null hypothesis that the samples are from the same population).

Selection of Estimation Models:

If we assume that coho salmon bound for each recovery area are randomly sampled as they migrate through the lower river tagging area, the recovery data (number of tagged or marked fish found and number of fish examined) from each recovery area can be used to estimate ρ, the percentage of the population that was tagged. If the hypothesis of equal $\hat{\rho}$ among recovery areas was not rejected ($P > 0.10$), the tag recovery data from the different areas were pooled. The pooled data were then used in the tests to determine if the tag release-and-recovery data were consistent with the Petersen model. We feel that the variation in $\hat{\rho}$ among the recovery areas generally reflects sampling variation in the recovery areas. The number of carcasses examined for tags was relatively small from some recovery areas. In some cases, all samples were collected from a relatively discrete area within the general recovery area which could influence the proportion of tagged carcasses present. Generally, the areas with greatly different recovery percentages (more than a 0.5% difference from the major recovery areas) had less than seven tag recoveries each. The different population estimates that were generated using the data from different recovery areas (or pooled recovery areas) were usually not significantly different from each other. Therefore, we selected the estimate with the smallest coefficient of variation as the "best" estimate of abundance for each year.

The model used to estimate abundance, simple Petersen or Darroch's stratified, was determined by the results of the tests for the consistency of the data. The four χ^2 tests used to determine consistency are described by Seber (1982) and by Eames et al. (1981, 1983).

Allocating Marked-Only Fish to Release Strata:

From 12% to 24% of the in-sample recoveries each year had a tag with an illegible number or had no tag and were identified as tagged fish by the opercula punches. The release stratum for these fish was unknown and had to be estimated for the stratified estimator. Marked fish with missing or illegible tags were allocated to release strata within a recovery area based on the proportional distribution of legible tags from each release stratum. This assumes that tag loss or tag illegibility is a random process and that coho salmon tagged during each release stratum have equal rates of tag loss, therefore, fish with missing or illegible tags are assumed to have a similar distribution for stratum of release as fish with legible tags. If tag loss (or a tag becoming illegible) is a time dependent process, then fish tagged during the earlier release strata might be expected to have higher rates of tag loss and this assumption would not be true. Eames et al. (1981, 1983) used procedures similar to ours to allocate fish recovered with missing tags to release strata in their study. Errors in the assignment of marked-only fish to release strata affect only the Darroch estimate.

For recovery area *j*, the number of tagged coho salmon recovered which were released during stratum *i* was estimated as:

$$\hat{r}_{ij} = U_j \left(\frac{t_{ij}}{\sum t_{ij}} \right) + t_{ij} \qquad [5]$$

where $\hat{r}_{ij}$ = the estimated number of tags recovered from release stratum *i*,

U_j = the number of fish recovered with missing or illegible tags in recovery area *j*, and

t_{ij} = the number of legible tags recovered in recovery area *j* that were released during release stratum *i*.

All estimates were rounded to the nearest 0.1 tag.

Tagging Mortality

Other fishery investigations have documented that tagging places considerable stress on fish and may cause premature death of some tagged individuals (Seber 1982). Unaccounted for tagging mortality causes the population to be over-estimated since there are fewer tags in the population available for recapture than the number originally released (*m*). Experiments to determine if jaw-tagged coho salmon experienced tagging mortality were conducted in 1986, 1987, 1988, and 1989. We feel it is more valuable to consider the results from these tests together rather than each year's experiment by itself. Therefore, we are presenting the tagging mortality experiments conducted during all years of the study. We feel the results of these experiments, considered as a whole, are applicable to each of the study years.

The fish in the treatment and control groups used in these experiments were monitored for premature mortality. Premature mortality was defined as the death of an "unripe" fish. It was assumed that fish which died prior to spawning would have died while holding in deep mainstem pools and would not have been easily recovered, while ripe and spawning fish would have moved up into spawning areas, and their carcasses could have been recovered at the same rate as other unmarked fish. The treatment and control groups were checked daily. During each check, observers recorded the date, weather conditions, and any signs of animal or human trespassing. If any dead fish were observed, the tag number (if present) or mark (if present), and spawning condition (spawned out, ripe, or unripe) were recorded.

Fisher's exact test was used to test the hypothesis that the mortality rates (number of coho salmon dying unripe before spawning) for the treatment and control groups were equal.

1986:

Three groups of coho salmon were used in the experiment: a jaw-tagged treatment group, a control group from Marblemount Hatchery, and a control group from the Baker River trap. The treatment group consisted of 47 coho salmon that were captured on 4 November with the beach seine at Lyman and jaw-tagged. The fish were then loaded into a transport truck and taken to Marblemount Hatchery where they were held in a raceway. The Marblemount control group consisted of 47 unmarked coho salmon that were removed from a holding pond at Marblemount on 6 November, loaded into a transport truck, driven for an amount of time equivalent to the treatment group, and put into the same raceway as the treatment group. The Baker control group was used to determine whether being held in a non-natal water supply put additional stress on the treatment group. On 7 November, 47 coho salmon with adipose fin clips were loaded from the Baker River trap into a transport truck, driven to Marblemount, and put into the same raceway as the other two groups.

1987:

In 1987 only two experimental groups were used, the treatment group and a single control group. The treatment group consisted of 25 coho salmon that were captured on 27 October with the beach seine at Lyman and jaw-tagged. The fish were then loaded into a transport truck and taken to a fenced-off section of Careys Creek where they were held. The control group consisted of 24 coho salmon taken from Clark Creek Hatchery on 27 October, loaded into a transport truck, driven for an amount of time equivalent to the treatment group, and put into the same section of Careys Creek. These fish were then monitored for a total of 106 days (from 27 October, 1987 through 10 February, 1988).

1988:

In 1988 two separate mortality tests were conducted, one in early October and one in early November, to determine whether tagging mortality was affected by the time of tagging.

The early-treatment group consisted of 25 coho salmon that were captured on 3 October with the beach seine at Lyman and jaw-tagged. The fish were then loaded into a transport truck and taken to a fenced-off section of Careys Creek where they were held. On the same day, 25 coho salmon trapped at Baker River were loaded into a transport truck, driven to Careys Creek, and released into the same stream section as the treatment group.

The late-treatment group consisted of 25 coho salmon that were captured on 10 November with the beach seine at Lyman and jaw-tagged. The fish were then loaded into a transport truck and taken to a fenced-off section of Careys Creek where they were held. On the same day, 25 coho salmon from Marblemount Hatchery were loaded into a transport truck, driven to Careys Creek, and released into the same stream section as the treatment group. These fish were monitored until 20 January, 1989 (there were no live fish remaining in the fenced-off section of Careys Creek after this date).

1989:

In 1989 there were two experimental groups, the treatment group and a single control group. The treatment group consisted of 24 coho salmon that were captured on 18 October with the beach seine at Lyman and jaw-tagged. The fish were then loaded into a transport truck and taken to a fenced-off section of Careys Creek where they were held. On the same day, 25 coho salmon trapped at Baker River were loaded into a transport truck, driven to Careys Creek, and released into the same stream section as the treatment group. These fish were then monitored for 35 days (from 18 October through 22 November).

Additional Analyses

Several additional analyses of the data collected during tagging and tag recovery surveys were conducted. These included analyses to determine the timing of the migration of different spawning groups through the tagging area and analyses of sex and length composition data. These analyses were not required for the abundance estimates but were conducted to describe the characteristics of the annual return of coho salmon to the Skagit River during the study years.

Migratory Timing to Major Recovery Areas:

The timing of coho salmon migrating through the lower river tagging area was estimated from an analysis of the release dates of the tags recovered in each major recovery area (excluding commercial and test fisheries). Only areas with ten or more legible tag recoveries were included in the analyses. Ten, 10-day time periods were defined for the migratory timing calculations: (1) 1 September to 10 September; (2) 11 September to 20 September; (3) 21 September to 30 September; (4) 1 October to 10 October; (5) 11 October to 20 October; (6) 21 October to 30 October; (7) 31 October to 9 November; (8) 10 November to 19 November; (9) 20 November to 29 November; and (10) 30 November to 9 December.

Catch-per-unit effort (CPUE) by the beach seine used to capture coho salmon for tagging was used to describe the timing of the run through the tagging area in the lower river. CPUE was calculated for each 10-day period as the total number of coho salmon caught divided by the total number of beach seine sets (catch per set). The number of tags recovered in each major recovery area from each of the release periods was used to estimate the CPUE of coho salmon bound for these areas. The CPUE of coho salmon from recovery area *j* during release period *i* was estimated by:

$$\hat{\omega}_{ij} = \frac{r_{ij}}{f_i} \qquad [6]$$

where $\hat{\omega}_{ij}$ = the estimated CPUE of coho salmon from recovery area *j* during release period *i*,

r_{ij} = the number of tags recovered in area *j* that were released during period *i*, and

f_i = the number of beach seine sets made during period *i*.

For each area analyzed, the CPUE estimated for each 10-day period was summed across all ten time periods to estimate a season total CPUE of coho salmon bound for that recovery area. The estimated CPUE of coho salmon from recovery area *j* during time period *i* was converted to the percentage of this season total CPUE for recovery area *j* to describe migratory timing (Mundy 1982). These data were then graphed so that the migratory timing patterns to the major recovery areas could be compared.

Analyses of Sex and Length Composition Data:

Significant differences in the probability of recovering coho salmon tagged during different release periods (π) were found at some recovery locations in 1986. Temporal trends in the probability of recovery could be due to changing environmental conditions at the tagging site which influenced the probability of capture. For example, high and low water conditions may have influenced the effectiveness of the beach seine used to capture fish in the tagging area. Under low water conditions a higher proportion of the coho salmon present might have been caught than under high water conditions. Another possible explanation is that physical characteristics of the fish themselves (for example, sex or length) may influence both rate of capture for tagging and rate of recovery in tag recovery samples. For example, the beach seine may capture larger coho salmon at a higher rate than smaller coho salmon so that a higher proportion of the larger fish were tagged. As long as there is random mixing of coho salmon tagged during different time periods in the recovery areas, and the recovery process does not have the same selectivity as the capture process, this presents no problems for the abundance estimates.

Significant differences in the probability of finding a tag during surveys conducted at different times in a recovery area (ρ) were often found. Temporal trends in the physical characteristics of the population, combined with temporal trends in capture efficiency at the tagging site, could cause the changes observed. During spawning ground surveys, male fish may be more likely to end up in locations that are sampled than female fish, or larger fish may have a higher

probability of being seen and sampled during spawning ground surveys than smaller fish. The available data were examined to determine if these influences were present. The data used in these analyses were the length and sex composition data for all coho salmon tagged at the lower river tagging site and the tag recovery data used for the population estimates. Coho salmon recovered with a missing or illegible tag but having an operculum punch could not be used since their length and sex were not recorded at time of recovery.

Seber recommends testing the release (tagging) and recovery (escapement) samples for randomness with respect to length. The recovery sample was tested by comparing the length distributions of individuals that were tagged but not recovered to those individuals that were tagged and recovered. Both a Mann-Whitney U test and a Kolmogorov-Smirnov (K-S) test (Conover 1980) were used to compare the length distributions of coho salmon from these two groups. These same tests were also used to compare the length distributions of male and female coho salmon that were tagged in the lower Skagit River.

If there was a significant difference between the length distributions of male and female coho salmon subsequent analyses were conducted for each sex separately. If there was a significant difference between the length distributions of coho salmon which were tagged but not recovered and those that were tagged and recovered, K-S tests were performed sequentially on the length distributions to determine length categories with no significant difference between these two groups. Testing began between 65 and 70 cm (above which the length distributions of the two groups were not significantly different) and length was sequentially decreased by one cm intervals until a significant difference ($P \leq 0.05$) between the groups was found. A K-S test was then performed on those fish that were at the length of the significant difference or smaller. If there was a significant difference between the fish which were tagged but not recovered and those that were tagged and recovered the process was repeated for the fish in this smaller length range.

TAGGING MORTALITY TESTS RESULTS

The results of the tagging mortality studies are presented first since any conclusions from these studies are applicable to all years of the study. This is followed by the results of the mark-recapture portion of the study for 1986. The success of the tagging mortality studies varied from year to year. In some years, there were events which invalidated the experiments and did not permit a comparison of mortality between the treatment and control groups.

1986

There were no mortalities in the treatment group or the two control groups during the first week of the experiment (4 November through 12 November). On 13 November, a flood knocked down the barrier between the coho salmon in the tagging mortality study and the other coho salmon in the raceway. The two groups of fish mixed making it impossible to identify fish in the control groups. Therefore, a comparison of mortality rates between treatment and control groups was not possible. Any mortalities of the treatment (jaw-tagged) group were recorded for the duration of the experiment.

Three fish from the treatment group were accidentally spawned. The first natural death occurred on 26 November, 22 days after tagging, and the last recorded death was on 5 January 1987, 62 days after tagging (Table 1). Only 30 of the original 47 coho salmon that were jaw-tagged were recovered. The missing fish may have escaped or been among the 43 coho salmon with unreadable or lost jaw tags sampled at Marblemount Hatchery.

1987

Four of the 25 (16.0%) jaw-tagged coho salmon (the treatment group) died in an unripe condition before spawning. The dates of death of these fish were: 6 November (10 days after tagging), 13 December (47 days after tagging), 3 January 1988 (68 days after tagging), and 9 January 1988 (74 days after tagging). Only one of the 24 (4.2%) control group fish died unripe before spawning. It died on 3 January 1988 (68 days after capture). All other fish in the treatment and control groups were either ripe or spawned-out at death. There was not a significant difference (Fisher's exact test, $P = 0.35$) in mortality rates between the treatment and control groups.

1988

There was evidence of human and animal interference at the Careys Creek holding site throughout the period of the experiment (3 October 1988 through 20 January 1989). Of the 100 coho salmon placed in the fenced-off area of the creek, only 62 were recovered. Evidently the missing fish were removed by human or other predators. We assumed that these individuals were removed at random and they were not different (with respect to their eventual mortality) from the fish from the same group (treatment or control) that remained.

Table 1. Record of deaths for 30 jaw-tagged coho salmon used for the tagging mortality test in 1986.

Date of Death	Condition	Maturity	Eventual Fate	Days Alive After Tagging
24-Nov-86	Dark	Ripe	Spawned	20
26-Nov-86	Blush	Ripe	Natural Death	22
26-Nov-86	Blush	Ripe	Natural Death	22
26-Nov-86	Blush	Not Ripe	Natural Death	22
26-Nov-86	Blush	Not Ripe	Natural Death	22
01-Dec-86	Dark	Not Ripe	Natural Death	27
01-Dec-86	Dark	Ripe	Spawned	27
01-Dec-86	Dark	Not Ripe	Natural Death	27
01-Dec-86	Dark	Ripe	Natural Death	27
01-Dec-86	Dark	Ripe	Natural Death	27
01-Dec-86	Dark	Ripe	Natural Death	27
02-Dec-86	Dark	Ripe	Spawned	28
02-Dec-86	Dark	Ripe	Natural Death	28
03-Dec-86	Dark	Not Ripe	Natural Death	29
04-Dec-86	Dark	Ripe	Natural Death	30
05-Dec-86	Dark	Ripe	Natural Death	31
05-Dec-86	Blush	Not Ripe	Natural Death	31
05-Dec-86	Dark	Ripe	Natural Death	31
11-Dec-86	Blush	Not Ripe	Natural Death	37
15-Dec-86	Dark	Not Ripe	Natural Death	41
15-Dec-86	Dark	Not Ripe	Natural Death	41
17-Dec-86	Dark	Ripe	Natural Death	43
22-Dec-86	Dark	Not Ripe	Natural Death	48
22-Dec-86	Dark	Ripe	Natural Death	48
24-Dec-86	Blush	Not Ripe	Natural Death	50
29-Dec-86	Dark	Ripe	Natural Death	55
29-Dec-86	Dark	Ripe	Natural Death	55
29-Dec-86	Dark	Ripe	Natural Death	55
05-Jan-87	Blush	Not Ripe	Natural Death	62
05-Jan-87	Blush	Ripe	Natural Death	62

Only 12 of the 25 fish in the jaw-tagged treatment group from 3 October were recovered. Of these, three of the 12 (25.0%) died in an unripe condition before spawning. The dates of death of these fish were: 16, 17, and 22 October (13 days, 14 days, and 19 days after tagging, respectively). Fifteen of the 25 fish in the control group from 3 October were recovered. Of these, only one (6.7%) died in an unripe condition before spawning. The date of death of this fish was 6 December (64 days after capture). All other fish recovered from the treatment and control groups were either ripe or spawned-out at death. There was not a significant difference (Fisher's exact test, $P = 0.29$) in the mortality rates between the treatment and control groups for the 3 October experiment.

Nineteen of the 25 fish in the jaw-tagged treatment group from 10 November were recovered. Of these, only one (5.3%) died in an unripe condition before spawning. The date of death of this fish was 6 December (26 days after tagging). Sixteen of the 25 fish in the control group from 10 November were recovered. None of this group died in an unripe condition before spawning. All other fish recovered from the treatment and control groups were either ripe or spawned-out at death. There was not a significant difference (Fisher's exact test, $P = 1.00$) in the mortality rates between the treatment and control groups for the 10 November experiment.

1989

There were no mortalities in the treatment group or the control group during the first nine days of the experiment (18 October through 27 October). On 27 October, two jaw-tagged coho salmon were found dead and in an unripe condition. A flood allowed most of the fish being held to escape on 1 November. Therefore, a comparison of mortality rates between treatment and control groups was not possible.

Conclusions

Despite the problems that occurred during the tagging mortality experiments, we feel that considered as a whole these experiments present no conclusive evidence of significant tagging mortality of jaw-tagged coho salmon. Tagging mortality is usually expected to occur during the first 24 hours after tagging (Paulik 1963). In all years (1986-1989), there were no mortalities in the treatment group during the first nine days after tagging. In 1987 and 1988, although the treatment groups had a higher rate of mortality than the control groups, these rates were not significantly different. However, the power (Peterman 1990) of the above tests to detect differences in mortality rates less than 30% was low (power for the tests ranged from 0.25 to 0.39) because of the small sample sizes.

Eames et al. (1981, 1983) conducted a series of tests designed to detect tagging mortality in the coho salmon tagged during their studies. They tested recovery rates by condition of release, set size (i.e., number of fish captured in the purse seine set), and tagging order for the coho salmon tagged at all release locations during their studies in both 1976 and 1977. None of these tests resulted in significant ($P \leq 0.05$) differences among the various categories tested. In addition to these tests, in 1977 they conducted a treatment-control type experiment similar

to the ones described in our study. They held 15 tagged and 15 untagged coho salmon in a holding pen for approximately 46 hours. No mortalities were observed. In a similar experiment, 36 tagged coho salmon were held for about 21 hours in a pen. One fish, judged to be in poor condition at the time of release, died before release. Based on this evidence, they concluded that their tagging operation did not result in a significant increase in mortality rates. We feel our data support a similar conclusion, therefore, we did not adjust the tag releases to account for any tagging mortality.

TAG RELEASE-AND-RECOVERY RESULTS

The results of the tagging conducted in 1986 are summarized in the following five sections. The summary consists of: (1) tag releases by day; (2) tag recoveries by location; (3) abundance estimates produced using the tag release-and-recovery data; (4) additional analyses which include migratory timing information from the release-and-recovery data and sex-length composition data; and (5) a discussion of the "best" estimate of the number of coho salmon migrating through the tagging area in the lower Skagit River.

There are two different tag recovery percentages presented in the results: the percentage of tags recovered from the tag releases during a specific time stratum (π) and the percentage of tagged fish in samples collected during tag recovery surveys (ρ). The recovery data from each major area were tested to determine if there were significant temporal differences in both of these percentages. The results of these tests determined which data were pooled and which model was used to estimate the abundance of coho salmon using the recovery data for a specific area or group of areas pooled.

Tag Releases

Tagging began on 15 September and continued through 14 November. A total of 1,689 coho salmon were tagged during 26 days of tagging (Table 2). About 18% of the tagged fish were eventually recovered during surveys conducted to estimate the percentage of tagged fish in the escapement.

The percentage of each day's release of tags that was recovered ranged from 0% to 31% (Figure 5). Generally, coho salmon tagged and released during the first month of tagging (15 September through 15 October) were recovered at a higher rate than those tagged and released during the second month of tagging (20 October through 14 November). Four temporal release strata were defined to determine if there were significant differences in π among the release strata using the recoveries at each major area. The four release strata were:

1. 15 September through 24 September;
2. 29 September through 8 October;
3. 13 October through 22 October; and
4. 28 October through 14 November.

Significant differences in π among the release strata were found for the recoveries at Baker River trap, Lower Sauk sub-basin spawning grounds, all spawning grounds from the Middle Skagit sub-basin and above combined, the commercial fishery, and for all recovery data combined (Table 3). There were no significant temporal differences in π among release strata for the recoveries at Marblemount Hatchery and Middle Skagit sub-basin spawning grounds. These tests were conducted only for recovery areas with seven or more legible tag recoveries.

Table 2. Number of coho salmon tagged each day and number of in-sample tag recoveries from each day's release for the Skagit River, 1986.

	Number	Tag Recoveries by Area[a]											Recoveries	
Date	Tagged	MMH	BAK	MSK	USK	LSA	MSA	USA	SUI	OTH	CFS	TFS	Total	% (π)
15-Sep	33	0	2	0	0	0	1	0	0	0	0	0	3	9.1%
16-Sep	36	3	1	0	0	0	0	0	1	0	6	0	11	30.6%
17-Sep	5	0	0	0	0	0	0	0	0	0	1	0	1	20.0%
18-Sep	57	1	3	0	0	0	0	0	0	0	6	0	10	17.5%
22-Sep	51	5	3	0	0	0	0	0	0	0	2	0	10	19.6%
23-Sep	78	2	4	1	0	0	1	0	0	0	3	0	11	14.1%
24-Sep	105	9	5	1	0	0	1	0	0	0	7	0	23	21.9%
29-Sep	115	7	8	0	0	0	1	0	0	0	4	1	21	18.3%
30-Sep	86	5	1	1	0	1	0	0	0	0	4	0	12	14.0%
01-Oct	21	0	1	0	0	0	0	0	1	0	1	0	3	14.3%
06-Oct	125	5	3	0	0	2	0	0	0	0	8	0	18	14.4%
07-Oct	17	1	1	0	0	0	0	0	0	0	0	0	2	11.8%
08-Oct	10	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
13-Oct	170	8	3	1	0	0	0	0	1	1	6	0	20	11.8%
14-Oct	26	0	1	1	0	0	0	0	0	0	5	1	8	30.8%
15-Oct	190	14	5	1	0	0	0	0	0	0	11	0	31	16.3%
20-Oct	126	7	0	0	0	1	0	0	1	0	2	0	11	8.7%
21-Oct	57	3	0	0	0	0	0	0	0	0	2	0	5	8.8%
22-Oct	20	2	0	0	0	0	0	0	0	0	1	0	3	15.0%
28-Oct	141	5	0	0	0	0	1	1	0	0	2	0	9	6.4%
29-Oct	82	5	0	1	0	1	0	0	0	0	0	0	7	8.5%
30-Oct	26	1	1	0	0	0	0	0	0	0	0	0	2	7.7%
31-Oct	19	1	0	1	0	0	1	0	0	0	0	0	3	15.8%
04-Nov	2	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
05-Nov	78	3	1	3	1	2	0	0	0	0	2	0	12	15.4%
14-Nov	13	1	0	0	0	0	0	0	0	0	0	0	1	7.7%
UNKNOWN[b]		49	5	5	2	4	3	0	4	1	0	0	73	
TOTALS	1,689	137	48	16	3	11	9	1	8	2	73	2	310	
% Recovered		8.1%	2.8%	0.9%	0.2%	0.7%	0.5%	0.1%	0.5%	0.1%	4.3%	0.1%	18.4%	

[a] Locations are: MMH - Marblemount Hatchery; BAK - Baker River trap; MSK - Middle Skagit sub-basin; USK - Upper Skagit sub-basin; LSA - Lower Sauk sub-basin; MSA - Middle Sauk sub-basin; USA - Upper Sauk sub-basin; SUI - Suiattle sub-basin; OTH - Cascade, Nookachamps, and Carpenter sub-basins; CFS - Commercial fishery; and TFS - Test fishery.

[b] Fish recovered with no tag but having the secondary mark (an operculum punch) or an illegible tag.

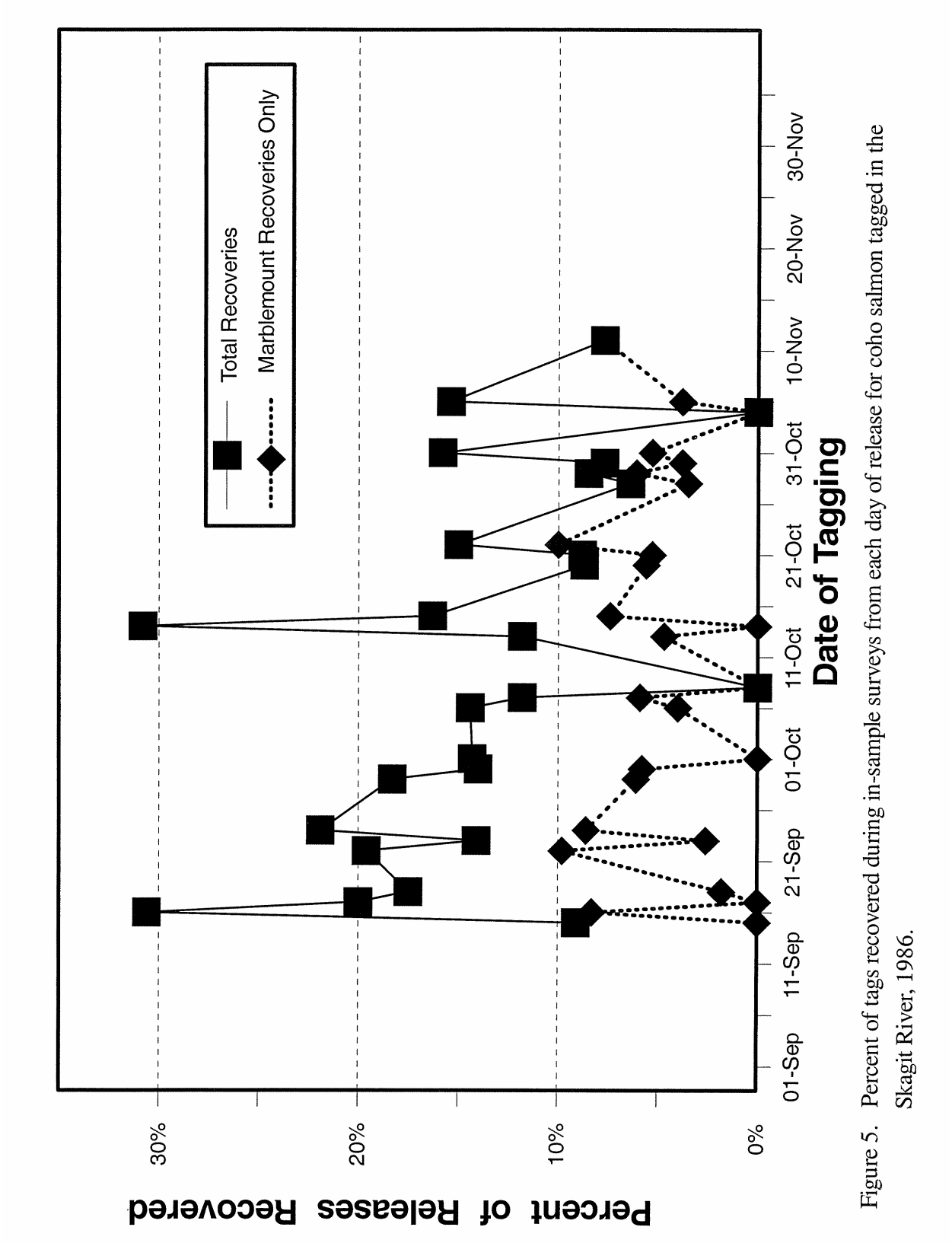

Figure 5. Percent of tags recovered during in-sample surveys from each day of release for coho salmon tagged in the Skagit River, 1986.

Table 3. Summary of the number of tag recoveries (#) from each release stratum in each major recovery area and the results of testing recovery percentages (π) for equality among release strata, 1986.

		RECOVERY AREA													
	Number	Marblemount		Baker R.		Mid. Skagit		Lower Sauk		Spawn. Gr.[a]		Comm. Fishery		Total	
Release Strata	Tagged	#	π	#	π	#	π	#	π	#	π	#	π	#	π
15-Sep thru 24-Sep	365	20	5.5%	18	4.9%	2	0.5%	0	0.0%	6	1.6%	25	6.8%	69	18.9%
29-Sep thru 8-Oct	374	18	4.8%	14	3.7%	1	0.3%	3	0.8%	6	1.6%	17	4.5%	56	15.0%
13-Oct thru 22-Oct	589	34	5.8%	9	1.5%	3	0.5%	1	0.2%	6	1.0%	27	4.6%	78	13.2%
28-Oct thru 14-Nov	361	16	4.4%	2	0.6%	5	1.4%	3	0.8%	12	3.3%	4	1.1%	34	9.4%
TOTALS	1,689	88	5.2%	43	2.5%	11	0.7%	7	0.4%	30	1.8%	73	4.3%	237	14.0%
TEST RESULTS[b]															
Test Used:			χ^2		χ^2		ART		ART		χ^2		χ^2		χ^2
Significance (P):			0.81		< 0.01		0.28		0.09		0.07		< 0.01		< 0.01
			NS		***		NS		*		*		***		***

[a] Total for all spawning ground samples from the Middle Skagit sub-basin and above. The total does not include recoveries from Marblemount Hatchery, Baker River trap, or the Nookachamps and Carpenter sub-basins.

[b] Results of the tests to determine if the recovery percentages (π) were different among release strata. Test used: χ^2 = chi-square test, ART = approximate randomization test. NS = Not Significant, * = Significant, $0.05 < P \leq 0.10$, ** = Significant, $0.01 < P \leq 0.05$, *** = Significant, $P \leq 0.01$.

Tag Recoveries

Samples to estimate ρ were collected at 13 areas in the Skagit River drainage. A total of 35,953 coho salmon were examined of which 35,042 fish were considered in-sample and 911 were not considered part of the population subject to tagging. Sample surveys were conducted at: Marblemount Hatchery; Baker River trap; spawning grounds in the Middle Skagit, Upper Skagit, Lower Sauk, Middle Sauk, Upper Sauk, Suiattle, Cascade, Nookachamps, and Carpenter sub-basins; and in commercial and test fisheries. Of the 310 in-sample recoveries, 73 fish (24%) had a tag with an illegible number or had a missing tag and were identified as tagged by an operculum punch. The largest number of tags were recovered at Marblemount Hatchery (137 recoveries or 44% of all in-sample recoveries). The areas with the next largest number of tag recoveries were the commercial fishery (73 or 24%) and Baker River (48 or 15%). Combined, these three areas account for 83% of all in-sample recoveries.

The percentage of tagged fish in the escapement samples (ρ) from the seven recovery areas having seven or more tag recoveries ranged from 0.4% for Middle Sauk sub-basin spawning ground samples to 1.1% for Marblemount Hatchery samples (Table 4). There was a significant difference (χ^2, $P < 0.01$) in ρ among these seven areas.

The average number of days between release and recovery for in-sample tag recoveries was about 39 days (Table 5). Tagged coho salmon recovered in the commercial fishery had the shortest average time between release and recovery, 12 days, and tag recoveries in the Lower Sauk sub-basin had the longest average time between release and recovery, 99 days. Tag recoveries at Baker River trap had the earliest average day of release (1 October) and recoveries in the Lower Sauk sub-basin had the latest average day of release (19 October).

Marblemount Hatchery:

Escapement samples were collected at Marblemount Hatchery from 3 November through 23 January. A total of 12,388 coho salmon were examined and 137 tagged fish (1.1%) were found (Appendix Table A-1). The Marblemount Hatchery sample is considered a census because all returning fish are sampled so the data were not examined for temporal differences in ρ. The mixture of the coho salmon used for the mortality test with the other coho salmon at Marblemount Hatchery (see page 21) complicated the estimate of ρ. It is possible that up to 17 of the tagged fish recovered could have come from the mortality test group and should not be included in the data used for the population estimate. Also, it is possible that up to 47 of the untagged fish examined at Marblemount could have been examined previously at Baker River and should not be included in the Marblemount Hatchery total. The complications caused by this are discussed in the Abundance Estimates section which follows.

Table 4. Summary of the percentage of tagged or marked coho salmon found in each recovery area during in-sample surveys of the Skagit River, 1986.

Recovery Area	Time Period	Fish Examined	Tags Found[a]	% Tagged (ρ)
Marblemount Hatchery	1. 03-Nov - 23-Jan	12,388	137	1.1%
Commercial Fishery	1. 26-Sep - 03-Oct	4,065	20	0.5%
	2. 10-Oct - 24-Oct	2,267	31	1.4%
	3. 25-Oct - 13-Nov	573	20	3.5%
	4. 20-Nov - 06-Jan	434	2	0.5%
	Total	7,339	73	1.0%
Baker River Trap	X.[b] 25-Aug - 17-Sep	594	0	0.0%
	1. 19-Sep - 23-Jan	5,041	48	1.0%
Middle Skagit Sub-basin	1. 29-Oct - 31-Dec	752	11	1.5%
	2. 06-Jan - 06-Feb	1,044	5	0.5%
	Total	1,796	16	0.9%
Lower Sauk Sub-basin	1. 26-Nov - 25-Feb	1,252	11	0.9%
Middle Sauk Sub-basin	1. 12-Nov - 25-Feb	2,110	9	0.4%
Suiattle Sub-basin	1. 02-Dec - 25-Feb	960	8	0.8%
Upper Skagit Sub-basin	1. 10-Nov - 26-Feb	446	3	0.7%
Upper Sauk Sub-basin	1. 25-Nov - 11-Feb	196	1	0.5%
Cascade Sub-basin	1. 19-Sep - 12-Feb	243	0	0.0%
Test Fishery (upstream)	1. 18-Sep - 29-Oct	523	1	0.2%
IN-SAMPLE TOTAL FOR UPSTREAM AREAS		32,294	307	1.0%
Carpenter Sub-basin	1. 28-Oct - 15-Jan	168	2	1.2%
Nookachamps Sub-basin	1. 03-Nov - 11-Feb	243	0	0.0%
Test Fishery (downstream)	X. 21-Aug - 5-Sep	317	0	0.0%
	1. 18-Sep - 07-Nov	2,337	1	<0.1%
IN-SAMPLE TOTAL FOR DOWNSTREAM AREAS		2,748	3	0.1%
TOTAL CONSIDERED IN POPULATION BEFORE TAGGING		911	0	0.0%
IN-SAMPLE TOTAL FOR ALL AREAS		35,042	310	0.9%
GRAND TOTAL FOR ALL SAMPLES		35,953	310	0.9%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

[b] X indicates that these fish were considered to be in the population before tagging began and not subject to tagging (i.e., they were not considered in-sample fish for the abundance estimates).

Table 5. Average day of release (DOR) and average number of days between release and recovery (DBET) for coho salmon tagged and recovered in the Skagit River, 1986.

Recovery Area	Sample Size[a]	Average DOR	Stand. Error	Range	Average DBET	Stand. Error	Range
Marblemount Hatchery:							
Pond Mortalities	21	9-Oct	2.6	16-Sep - 29-Oct	50.7	3.2	19 - 76
Surplused	30	9-Oct	3.1	16-Sep - 14-Nov	59.8	3.0	12 - 83
Spawned	37	11-Oct	2.1	22-Sep - 5-Nov	46.5	2.2	19 - 71
Commercial Fishery	73	4-Oct	1.5	16-Sep - 5-Nov	12.4	1.3	2 - 56
Baker River Trap	43	1-Oct	1.8	15-Sep - 5-Nov	27.3	2.1	8 - 64
Middle Skagit Sub-basin	11	17-Oct	5.1	23-Sep - 5-Nov	56.9	6.7	22 - 84
Lower Sauk Sub-basin	7	19-Oct	5.7	30-Sep - 5-Nov	98.6	7.4	69 - 127
Middle Sauk Sub-basin	6	5-Oct	8.0	15-Sep - 31-Oct	82.3	5.3	70 - 107
Suiattle Sub-basin	4	5-Oct	7.4	16-Sep - 20-Oct	97.5	8.4	78 - 119
Test Fishery	2	6-Oct	7.5	29-Sep - 14-Oct	16.0	1.0	15 - 17
Upper Skagit Sub-basin	1	5-Nov			83.0		
Upper Sauk Sub-basin	1	28-Oct			85.0		
Carpenter Sub-basin	1	13-Oct			59.0		
All Recoveries	237	7-Oct	0.9	15-Sep - 14-Nov	38.5	1.8	2 - 127

[a] Includes tag recoveries with legible numbers only.

Baker River Trap:

Escapement samples were collected at Baker River trap from 25 August through 23 January. Based upon a four-day minimum travel time from the tagging area to Baker River dam determined from all five years of tagging data (Appendix Table A-2), samples collected prior to 19 September were not considered in-sample. A total of 594 coho salmon were examined prior to 19 September. The average migration time of fish tagged in the lower river to the trap was 27 days (Table 5). A total of 5,041 coho salmon were examined for tags after 18 September and 48 tagged fish (1.0%) were found (Appendix Table A-3). The Baker River trap sample is considered a census because all returning fish are sampled so the data were not examined for temporal differences in ρ.

Commercial and Test Fishery Samples:

An in-river commercial fishery was conducted in the upper river between RM 8 and RM 57 on 11 days between 26 September and 6 January. A total of 7,339 coho salmon were examined for tags and 73 tagged fish (1.0%) were found. There was a significant difference (χ^2, $P < 0.01$) in ρ among the four temporal strata established for the commercial fishery (Appendix Table A-4).

Test fisheries were conducted on 25 days between 21 August and 7 November. Recovery data collected prior to 18 September were excluded from analysis since tagging did not begin until 15 September. A total of 317 coho salmon were examined prior to 18 September in the test fisheries. A total of 2,860 coho salmon were examined for tags after 17 September: one tag was found in 523 coho salmon examined (0.2%) from test fisheries conducted in areas above the tagging site and one tag was recovered in 2,337 fish examined (< 0.1%) from test fisheries conducted in areas below the tagging site (Appendix Table A-5).

Middle Skagit Sub-basin:

Tag recovery samples were collected during surveys of Middle Skagit sub-basin spawning grounds conducted from 26 November through 6 February and at the Hansen Creek trap operated from 29 October through 18 December. Surveys were conducted by SSC and WDFW crews. There was not a significant difference in ρ among samples collected by the two agencies or at the trap (ART, $P = 0.99$) so all samples were combined. A total of 1,796 coho salmon were examined for tags and 16 tagged fish (0.9%) were found (Appendix Table A-6). There was a significant difference (χ^2, $P = 0.03$) in ρ between samples collected on or before 31 December and samples collected after this date.

Upper Skagit Sub-basin:

Tag recovery samples were collected during surveys of Upper Skagit sub-basin spawning grounds conducted from 10 November through 26 February. Surveys were conducted by SSC and WDFW crews. A total of 446 coho salmon were examined for tags and 3 tagged fish (0.7%) were found (Appendix Table A-7).

Lower Sauk Sub-basin:

Tag recovery samples were collected during surveys of Lower Sauk sub-basin spawning grounds conducted from 26 November through 25 February. Surveys were conducted by SSC and WDFW crews. There was not a significant difference in ρ between samples collected by the two agencies (Fisher's exact test, $P = 0.62$) so the samples were combined. A total of 1,252 coho salmon were examined for tags and 11 tagged fish (0.9%) were found (Appendix Table A-8). The hypothesis of constant ρ for temporal strata in the recovery samples was not rejected.

Middle Sauk Sub-basin:

Tag recovery samples were collected during surveys of Middle Sauk sub-basin spawning grounds conducted from 12 November through 25 February. Surveys were conducted by SSC and WDFW crews. There was not a significant difference in ρ between samples collected by the two agencies (χ^2, $P = 0.34$) so the samples were combined. A total of 2,110 coho salmon were examined for tags and 9 tagged fish (0.4%) were found (Appendix Table A-9). The hypothesis of constant ρ for temporal strata in the recovery samples was not rejected.

Upper Sauk Sub-basin:

Tag recovery samples were collected during surveys of Upper Sauk sub-basin spawning grounds conducted from 25 November through 11 February. Surveys were conducted by SSC crews. A total of 196 coho salmon were examined for tags and only one tagged fish (0.5%) was found (Appendix Table A-10).

Suiattle Sub-basin:

Tag recovery samples were collected during surveys of Suiattle sub-basin spawning grounds conducted from 2 December through 25 February. Surveys were conducted by SSC crews. A total of 960 coho salmon were examined for tags and 8 tagged fish (0.8%) were found (Appendix Table A-11). The hypothesis of constant ρ for temporal strata in the recovery samples was not rejected.

Other Spawning Ground Surveys:

Spawning ground surveys were conducted in three other areas: Nookachamps sub-basin, Carpenter sub-basin, and Cascade sub-basin. Surveys of the Nookachamps sub-basin were conducted by SSC and WDFW crews. A total of 243 coho salmon were examined for tags and no tagged fish (0.0%) were found (Appendix Table A-12). Spawning ground surveys of the Carpenter sub-basin were conducted by SSC crews and a trap was operated by SSC on Fisher Creek. A total of 168 coho salmon were examined for tags and two tagged fish (1.2%) were found in these samples (Appendix Table A-13). SSC crews surveyed Cascade sub-basin spawning grounds and examined 243 coho salmon (Appendix Table A-14). No tags were recovered during surveys of the Cascade sub-basin.

Out-of-System Recoveries:

No jaw tags from the tagging conducted in the Skagit River during 1986 were recovered outside of the Skagit River system.

Abundance Estimates

Estimates of coho salmon abundance from the tag recovery data for each recovery area having seven or more tag recoveries are summarized in Table 6. The details of the abundance estimate for each location are in Appendix B. The complications with the Marblemount Hatchery data caused by the possible mixture of the fish from the tagging mortality test with the other coho salmon at the hatchery led us to produce several estimates from the Marblemount data. We considered all possible outcomes of the mixing on the Marblemount sample and produced minimum and maximum estimates. The minimum and maximum estimates, and the estimate we selected to be most likely, are summarized below. The selected estimate uses the data configuration we consider the most probable and the data reported in Tables 2, 3, 4, 5 and Appendix Table A-1 reflect this configuration. This configuration assumes that none of the unreadable tags recovered at Marblemount hatchery came from the 17 coho salmon which escaped the holding area used for the tagging mortality test.

Estimate	Estimate	St. Error	95% Confidence Interval
Minimum	151,144	12,216.5	130,425 - 182,555
Selected	151,719	12,263.3	130,922 - 183,241
Maximum	172,798	15,000.1	147,803 - 211,843

Because there was a significant difference in ρ between recovery samples collected before January and samples collected in January and February in the Middle Skagit sub-basin, the Petersen estimate was not appropriate. However, no feasible solutions to Darroch's stratified estimator were found[4]. Since the samples from Marblemount Hatchery and Baker River trap were both censuses they were compared to determine if it was appropriate to pool them. The two samples were not significantly different (χ^2, $P = 0.37$) so an estimate was generated with the pooled data. The three samples from sub-basins above the tagging area which had no significant (all $P > 0.05$) temporal differences in ρ (Lower Sauk, Middle Sauk, and Suiattle) were compared and no significant differences in ρ were found (χ^2, $P = 0.21$). The recovery data from these locations were pooled to generate an estimate, also. Finally, ρ for Marblemount Hatchery, Baker River trap, and the Lower Sauk, Middle Sauk, and Suiattle sub-basins were compared. There was a significant difference in ρ among these areas when the Middle Sauk sub-basin sample was included (χ^2, $P = 0.06$), but there was not a significant difference in ρ among the remaining four locations when the Middle Sauk sample was excluded (χ^2, $P = 0.66$). Therefore, samples from these four areas (Marblemount Hatchery, Baker River, Lower Sauk sub-basin, and Suiattle sub-basin) were pooled for an estimate.

[4] A solution to Darroch's equations that had all positive estimates for the P_{ij} was not found.

Table 6. Summary of estimates of the number of coho salmon in the Skagit River escapement using data from each major recovery area, 1986.

Recovery Area	Estimation Method	Estimated Abundance	Stand. Error	CV[a]	95% Confidence Interval
Marblemount	Petersen	151,719	12,263	8.1%	130,922 - 183,241
Commercial Fishery	Darroch	179,088	52,557	29.3%	76,075 - 282,100
Baker River	Petersen	173,897	24,116	13.9%	129,672 - 234,568
Marblemount - Baker pooled	Petersen	158,368	10,867	6.9%	139,173 - 185,747
Middle Skagit	no feasible estimate				
Lower Sauk	Petersen	176,463	48,534	27.5%	93,678 - 348,914
Middle Sauk	Petersen	356,758	106,994	30.0%	176,408 - 773,342
Suiattle	Petersen	180,453	56,645	31.4%	85,288 - 415,089
L. Sauk - M. Sauk - Suiattle pooled	Petersen	251,926	45,446	18.0%	170,963 - 376,673
Marblemount - Baker - L. Sauk - Suiattle pooled	Petersen	161,926	10,520	6.5%	143,082 - 188,325

[a] CV = coefficient of variation.

Estimates of the number of coho salmon migrating through the lower Skagit River tagging area ranged from 151,719 coho salmon using only Marblemount Hatchery recovery data to 356,758 coho salmon using Middle Sauk sub-basin spawning ground recovery data (Table 6). Pooled Marblemount-Baker-Lower Sauk-Suiattle data provided the most precise estimate (CV = 6.5%). The estimate with the largest CV was from Suiattle sub-basin recovery data (CV = 31.4%). The 95% confidence intervals for the abundance estimates overlapped for each recovery area.

Additional Analyses

The release data were divided into ten, 10-day time periods for the migratory timing analysis and to describe temporal patterns in the length and sex composition of tagged coho salmon. Coho salmon were tagged and released during seven of these periods.

Timing of Migrations to Major Recovery Areas:

The CPUE of coho salmon by the beach seine in the lower river tagging area is shown by day and for each 10-day period in Figure 6. CPUE peaked during the 11 October through 20 October time period. Three areas had ten or more recoveries of legible tags which could be used for the migratory timing calculations (Appendix Table A-15). Coho salmon from every period with tag releases were recovered at Marblemount Hatchery (Figure 7); this was the only area in which this occurred. CPUE of coho salmon bound for Marblemount Hatchery peaked during the 11 October to 20 October period. CPUE of coho salmon bound for Baker River peaked during the 21 September to 30 September period. Coho salmon from Middle Skagit sub-basin spawning grounds had the latest timing with about 55% of the total CPUE of this group occurring in the 31 October to 9 November period.

Length and Sex Composition Analyses:

The sex and length data for the 1,689 coho salmon tagged and released in the lower Skagit River and the 237 in-sample recoveries with legible tags were analyzed. Both the K-S and M-W tests which compared the lengths of coho salmon tagged but not recovered to the lengths of those tagged and recovered were significant ($P < 0.01$) indicating that the recovery samples were not random with respect to length of fish. There was also a significant difference between male and female length distributions (K-S test, $P < 0.01$), therefore, all subsequent analyses of length were conducted for each sex separately. It is evident from Figure 8 that male coho salmon had a higher proportion of smaller sizes (fish less than 50 cm) than female coho salmon. Coho salmon less than 50 cm in length composed 44% of the males that were tagged but only 18% of the female coho salmon that were tagged.

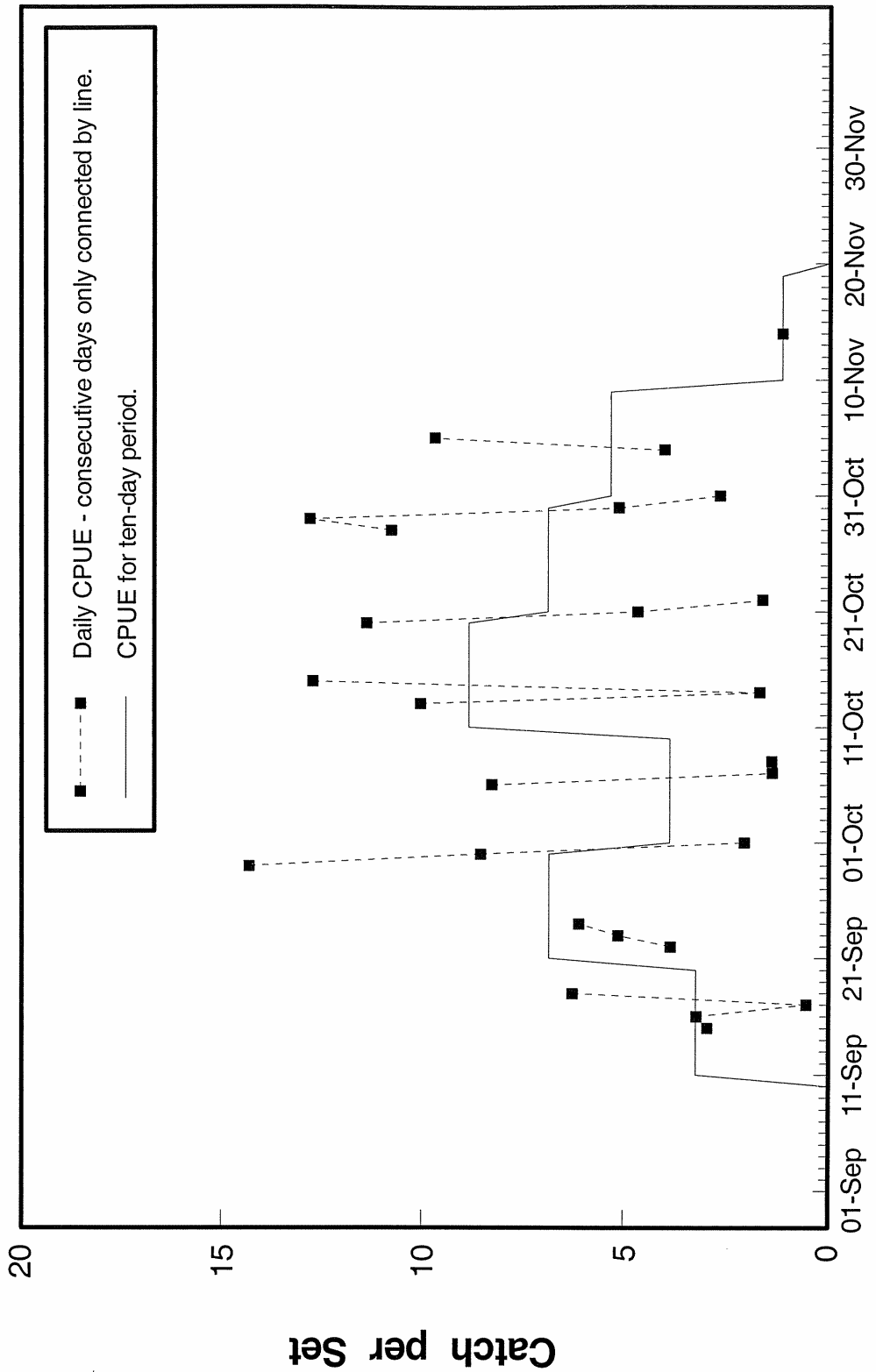

Figure 6. Catch-per-unit effort of coho salmon by the beach seine in the lower Skagit River tagging area by day and for each ten-day period, 1986.

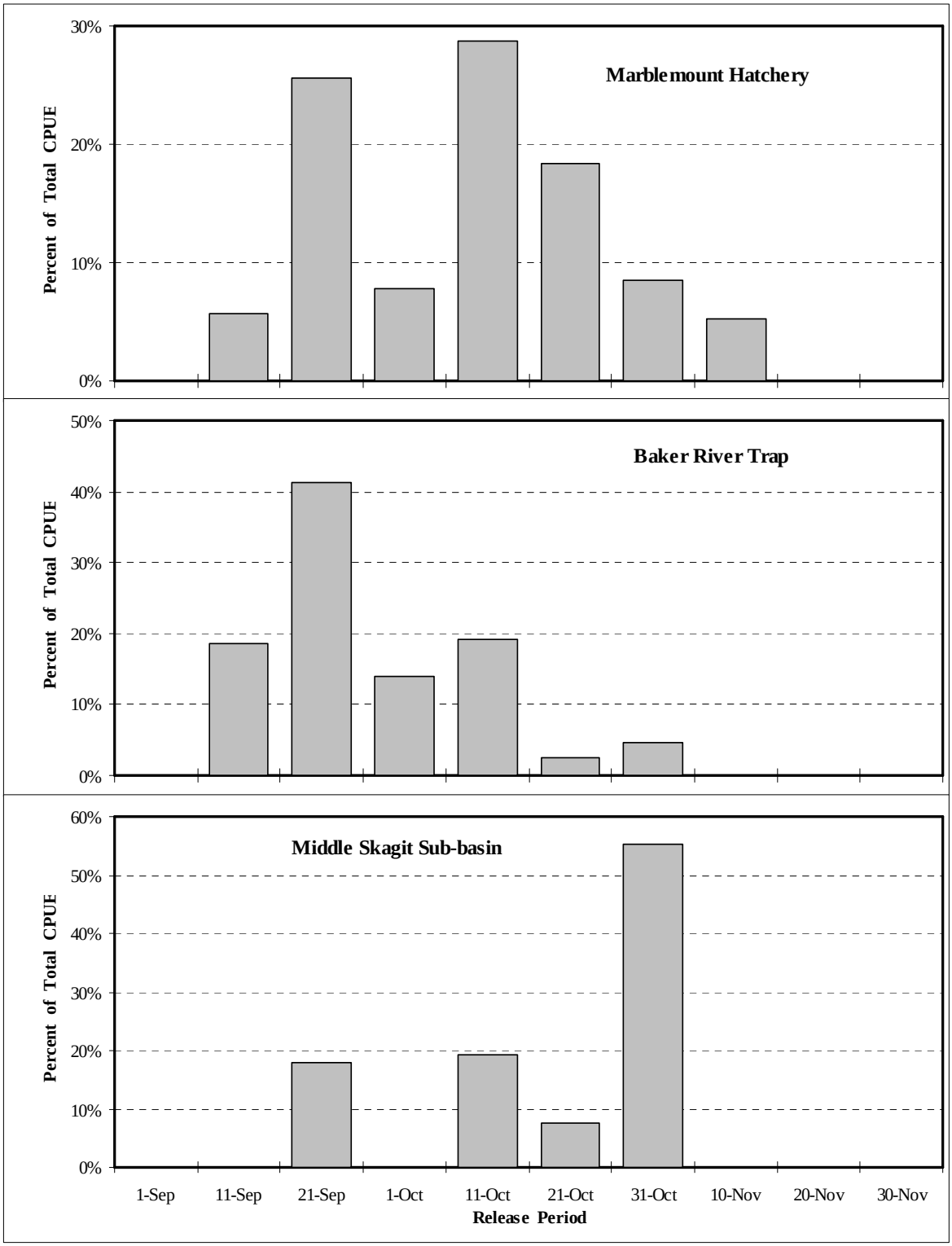

Figure 7. Beach seine catch-per-unit effort (CPUE) of coho salmon bound for major Skagit River tag recovery areas in 1986. CPUE is for ten-day periods (starting date of period shown) and is expressed as a percentage of the total CPUE for tagged fish recovered from the area.

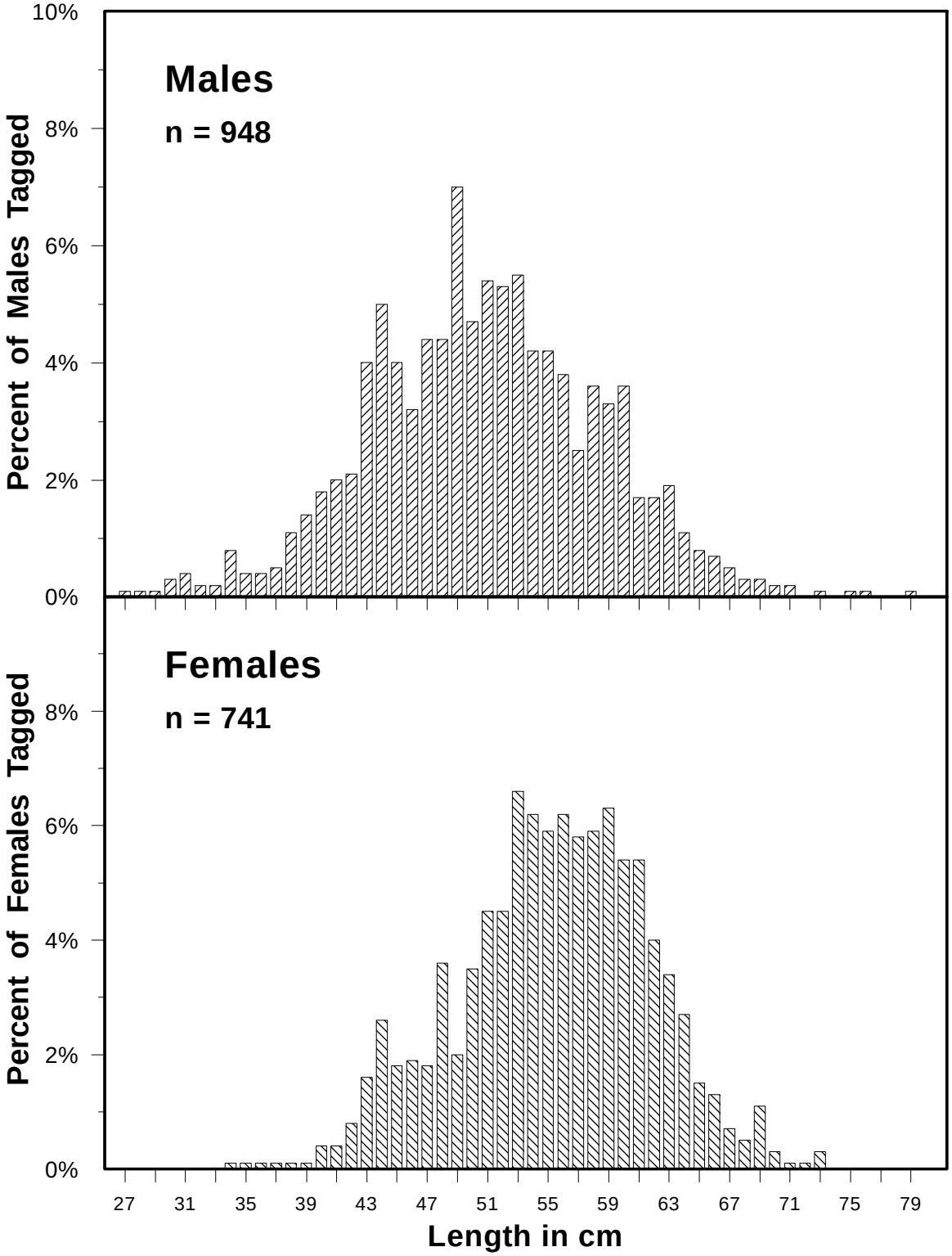

Figure 8. Comparison of length frequencies of male and female coho salmon tagged in the lower Skagit River, 1986.

Males Tagged male coho salmon averaged 50.9 cm in fork length (SE = 0.25). The mean length of male coho salmon that were tagged but not recovered was 50.3 cm (SE = 0.27) compared to a mean length of 54.6 cm (SE = 0.63) for male coho salmon that were tagged and recovered. The length distribution of male coho salmon that were tagged but not recovered was significantly different (K-S test, $P < 0.01$) from the distribution of those that were tagged and recovered (Figure 9). Three length categories were defined from the sequential K-S tests for male coho salmon: (1) fish with lengths less than 49 cm; (2) fish with lengths from 49 cm through 52 cm; and (3) fish with lengths greater than 52 cm. The percentages of tagged coho salmon in each length category that were recovered were 6.3%, 11.8%, and 20.0%, respectively (Appendix Table A-16).

Females Tagged female coho salmon averaged 55.3 cm in fork length (SE = 0.24). The mean length of female coho salmon that were tagged but not recovered was 55.4 cm (SE = 0.26) compared to a mean length of 55.2 cm (SE = 0.58) for female coho salmon that were tagged and recovered. The length distribution of female coho salmon that were tagged but not recovered was not significantly different (K-S test, $P = 0.79$) from the distribution of those that were tagged and recovered (Figure 9). Therefore, sequential K-S tests were not conducted (Appendix Table A-16).

Tag Recovery Rates There was not a significant difference (χ^2, $P = 0.23$) in tag recovery rates between male and female coho salmon. The highest rate of tag recovery, 20.0%, was for males in the largest (≥ 53 cm) length category (Appendix Table A-16). There was a significant difference (χ^2, $P = 0.10$) in tag recovery rates among the release condition categories. Coho salmon classified as x- had a 10.3% tag recovery rate while those classified as x+ had a 17.8% tag recovery rate (Appendix Table A-17). There was not a significant difference (χ^2, $P = 0.19$) in tag recovery rates among the maturity categories.

Sex-Length Composition There were temporal changes in both the sex composition and length composition for each sex during the tagging period (Figure 10). The percentage of males in the tagging samples declined from 62% to about 50% during the first three periods with tag releases. The percentage of females gradually increased from 38% to 50% during this same period. The percentage of small males (< 49 cm) and small females (≤ 52 cm) decreased throughout the tag release period and the percentage of large males (> 52 cm) and large females (≥ 53 cm) increased.

Conclusions

The tag recovery data consistently indicate that approximately 1% of the coho salmon migrating through the lower Skagit River tagging area were caught and tagged. The percentage of tagged or marked coho salmon in the samples from nearly all the major recovery areas (areas with seven or more tag recoveries) was near 1%: Marblemount 1.1%; Baker River trap 1.0%; commercial fishery 1.0%; Middle Skagit sub-basin 0.9%; Lower Sauk sub-basin 0.9%; and Suiattle sub-basin 0.8%. The one exception was the Middle Sauk sub-basin sample

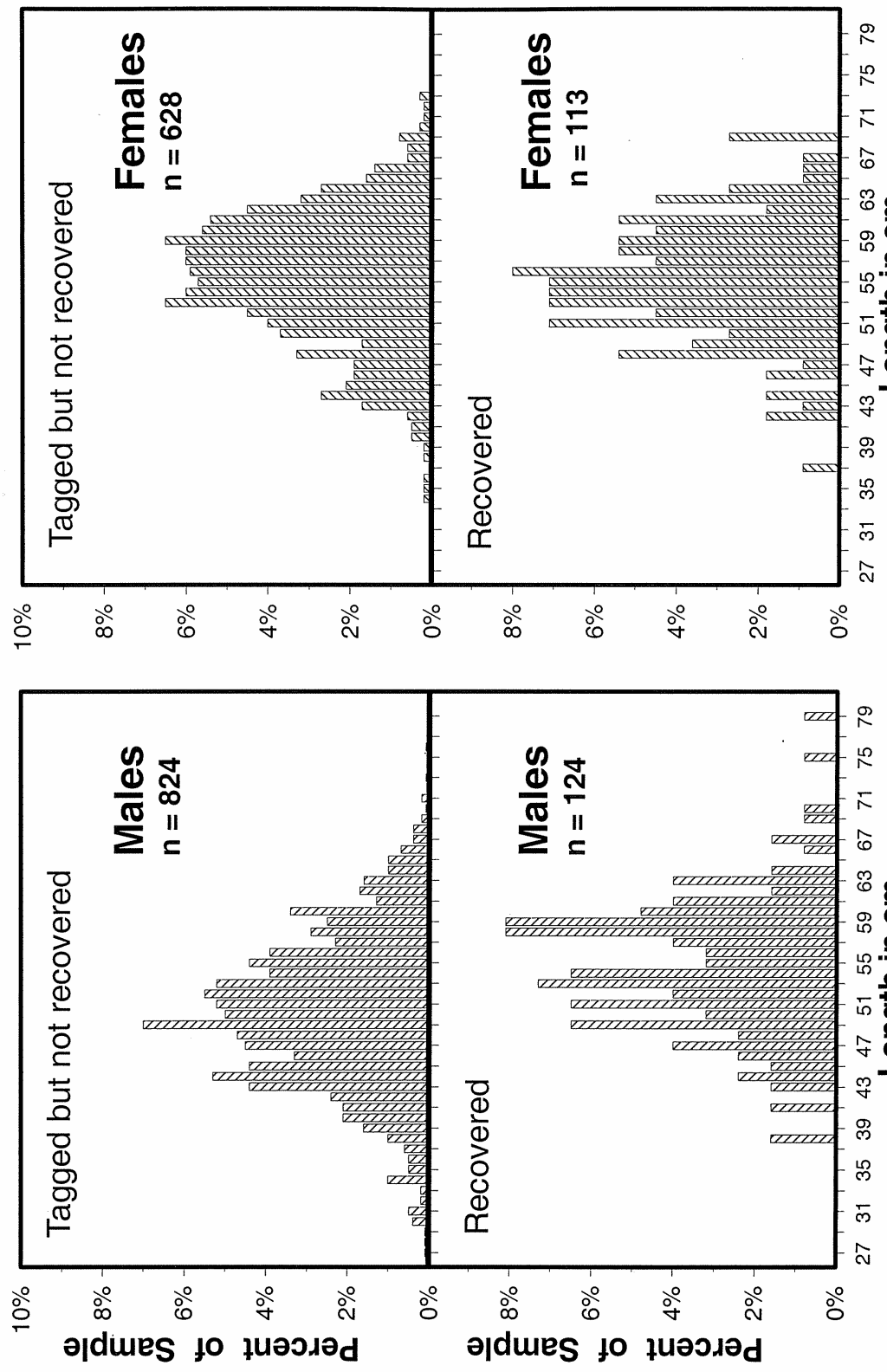

Figure 9. Comparison of length frequencies of coho salmon that were tagged but not recovered to those that were tagged and recovered, for males and females, 1986.

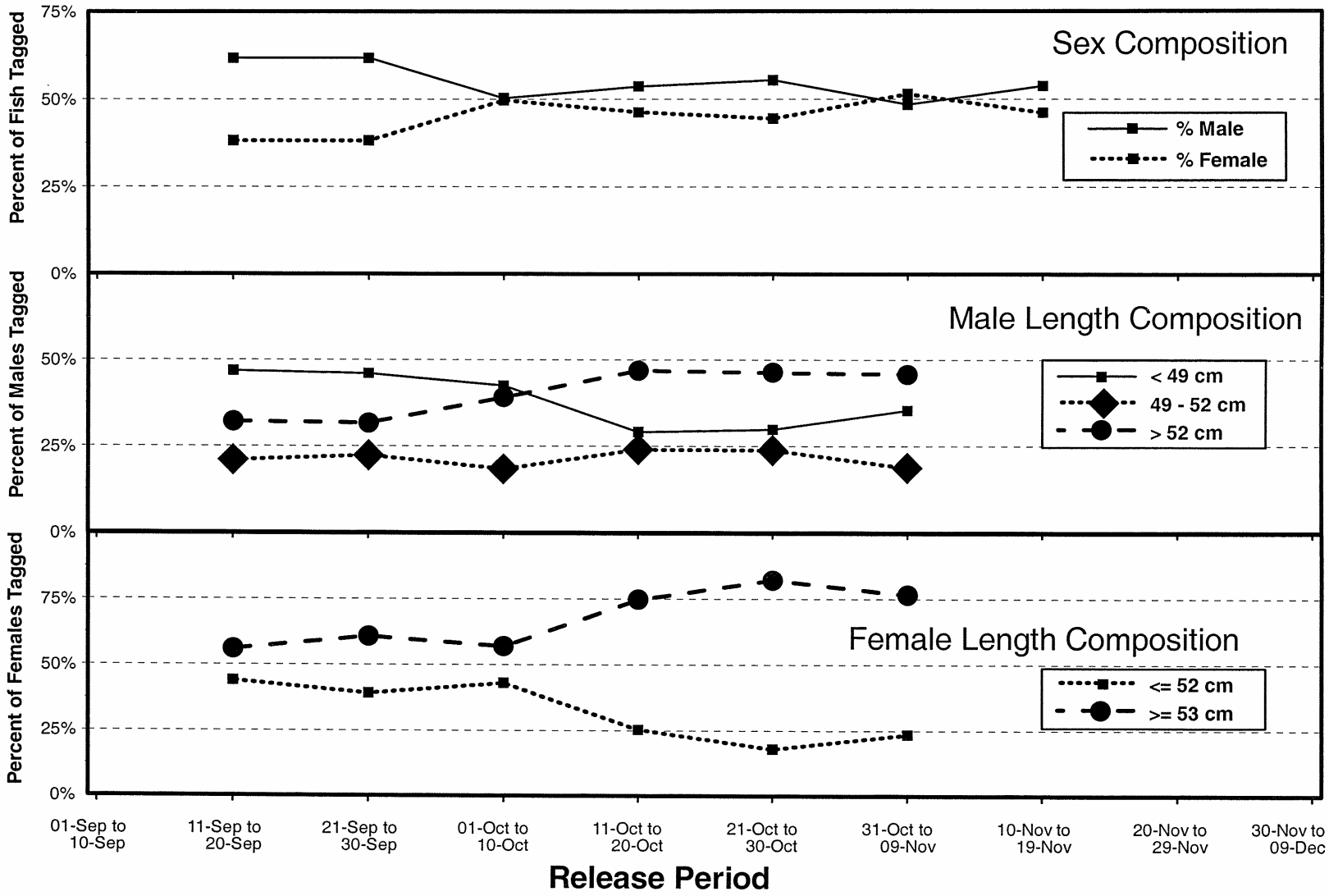

Figure 10. Sex and length composition, by release period, of coho salmon tagged in the lower Skagit River, 1986.

where only 0.4% of the fish examined were tagged or marked. The tag recovery data indicate that some coho salmon from spawning areas substantially downstream of the tagging site were present in the tagging area. There were two tags recovered in 411 coho salmon examined (0.5%) during spawning ground surveys in the Nookachamps and Carpenter sub-basins.

We recommend that the estimate using the pooled Marblemount-Baker-Lower Sauk-Suiattle data be considered the "best" estimate of coho salmon abundance for 1986. There was not a significant difference in ρ among these areas. The samples from two of the areas (Marblemount Hatchery and Baker River trap) are censuses. There were no temporal differences in ρ for the samples from the two sub-basins. This estimate uses the largest number of tag recoveries (204) and therefore has the smallest CV. We do not recommend combining the recovery data from the commercial fishery or the Middle Skagit sub-basin, even though ρ for these areas was not significantly different from the pooled areas, because of the temporal differences in ρ for the samples from these recovery areas. The estimate, 161,926 coho salmon (95% confidence interval: 143,082 to 188,325 fish), is for the number of fish present in the lower Skagit River tagging area during the period 15 September to 14 November. This estimate includes coho salmon bound for all spawning grounds above the tagging area and some portion of the escapement to areas downstream of the tagging site.

DISCUSSION

The methods used to estimate the number of coho salmon in the escapement to the Skagit River using the tag release-and-recovery data and the assumptions necessary for these estimates have been described. A discussion of how well the data meet the major assumptions for the Petersen model and a definition of the "population" which is being estimated follows.

Population was Closed

We assume that some coho salmon migrated through the tagging area before and after the period of tagging (15 September through 14 November). Under alternate assumptions 1a or 1b (described in the Methods section), the population can be open but the exact point in time to which the estimate applies must be specified. We feel the trend in CPUE for the beach seine used to capture coho salmon for tagging provides strong evidence that the tagging period encompassed the major portion of the coho salmon migration. The CPUE was low when tagging began and was followed by an increase in CPUE to a peak during the period 11 October through 20 October. This was followed by a decline in CPUE in early and mid November (Figure 6).

Coho salmon were counted at the Baker River trap prior to tagging in 1986. Adjustments were made to the total number of fish examined at Baker River trap to account for this so that the Baker River sample data would not bias the results. Therefore, the estimate includes only the portion of the population migrating through the tagging area after tagging began.

If we assume there is recruitment to the population (coho salmon migrating through the tagging area after tagging ends) but no mortality before the fish reached their spawning areas (assumption 1b), and there is complete mixing of the fish on the spawning grounds, then the abundance estimate includes coho salmon migrating through the tagging area after the last day of tagging. Sampling at Marblemount Hatchery and at Baker River trap occurred through 23 January. Tag recovery surveys were conducted in most sub-basin spawning grounds until mid or late February. We feel there was sufficient time for coho salmon migrating through the tagging area after tagging had ended to mix with the fish already present on the spawning grounds and at Marblemount Hatchery.

Area Encompassed by the Estimates:

The Petersen model estimates the number of coho salmon migrating though the tagging area in the lower river during the time period defined above. The estimate includes all coho salmon bound for spawning areas above the tagging area (including Marblemount Hatchery and Baker River) and all spawning areas in the Middle Skagit sub-basin above and including Hansen Creek (Figure 1). Even though Hansen Creek is below the tagging area, the percentage of tagged coho salmon found in samples at the trap was not significantly different from samples collected from other spawning grounds in the Middle Skagit sub-basin and was similar to other upstream spawning areas. However, the tag release-and-recovery data suggest that only a

fraction of the coho salmon which spawned in the Carpenter and Nookachamps sub-basins passed through the tagging area. The percentage of tags in the samples from these areas combined, 0.1% (including test fishery samples), was much smaller than in the upstream recovery areas. This indicates that only a portion of the coho salmon from these areas passed through the tagging area. Therefore, we conclude that the abundance estimate does not include all of the coho salmon which spawned in the Carpenter and Nookachamps sub-basins. If the total number of tagged fish that migrated to these downstream areas could be estimated, this number could be removed from the total number of tags released (*m* in equation 1) and the abundance estimate would include only coho salmon bound for areas **upstream** of the tagging site and the Middle Skagit sub-basin. We estimated the number of tags "lost" to these downstream areas so that we could examine the effect of these tags on the abundance estimate for the upstream areas.

Estimate of the Number of Tagged Fish "Lost" to Areas Downstream of the Tagging Area:

Three groups of fish from areas downstream of the tagging area were examined for tags: (1) commercial fishery catches; (2) test fishery catches; and (3) fish spawning in the Carpenter and Nookachamps sub-basins. We were not able to allocate the commercial catch in area 78D to its subareas (78D-2, 78D-3, and 78D-4; see Figure 4) in 1986. Therefore, we assumed that the entire 78D commercial catch was included in the abundance estimate. The tag recovery data support this as the total percentage of tags found in commercial fishery samples (ρ = 1.0%) was similar to that observed at all the upstream recovery areas with seven or more tag recoveries but one (Table 4). There were no samples inspected for tags from the commercial fishery catches in areas 78C and 8, 8E (inner Skagit Bay), therefore, we applied the percentage of tags found in downstream test fishery samples (Area 2, Spudhouse, Blakes, Bay, and Jetty; see Figure 4) to these catches. The numbers of tagged fish present on spawning grounds in the Carpenter and Nookachamps sub-basins were estimated by applying the percentage of tags found during in-sample surveys of these sub-basins combined (two tagged fish found in 411 fish examined for ρ = 0.49%) to an independent estimate of the number of coho salmon spawning in these sub-basins. The spawning ground escapement to these sub-basins was estimated using a redd-count method (Conrad et al. 1993). The numbers used for these calculations are summarized in Appendix Table A-18. We estimated that a total of 63 tags could have been "lost" to these downstream areas. If the number of tags released is adjusted to 1,626 (1,689 - 63), then (using the pooled Marblemount-Baker-Lower Sauk-Suiattle recovery data) the estimated abundance for areas upstream of the tagging area becomes 155,889 coho salmon. This is 6,037 fish less than the "unadjusted" estimate which is about a four percent difference.

The presence of coho salmon bound for systems outside the Skagit River in the tagging area would also affect the abundance estimate. In 1986, there were no out-of-system recoveries of coho salmon tagged in the lower Skagit River. Therefore, we do not feel that either: (1) the loss of tagged coho salmon to systems outside the Skagit River or (2) the contribution of coho salmon bound for systems outside the Skagit River was a major source of error.

All Coho Salmon Have an Equal Probability of Capture During Tagging or the Recovery Sample is a Simple Random Sample of the Population

These assumptions are often hard to satisfy as it is difficult or impossible to obtain simple random samples from highly dispersed and mobile populations. Fortunately, the estimates are still valid under certain alternative assumptions. Junge (1963) demonstrated that selectivity (non-randomness) may exist in both the tagging and recovery samples without introducing bias in the estimate if the sources of selectivity in the two samples are independent.

During the Skagit River study, there is evidence that the tagging sample may not have been random with respect to time. Certain portions of the population may have been tagged at higher rates than others. There is also evidence that the recovery samples on the spawning grounds were selective with respect to the length of the fish, at least for males. Eames et al. (1981, 1983) found that there was a correlation between time of entry and size of coho salmon for the returns to the Skagit River in 1976 and 1977. Smaller fish generally arrived earlier in the run than larger fish. This presents a problem if timing of passage through the tagging area is correlated with the size of fish and area of spawning (Junge 1963). If such selectivity existed the population estimates would contain a negative bias. However, we believe if such a bias exists it is small because the majority of the tag recovery data used for the abundance estimate were collected from areas where there was no size selectivity (Marblemount Hatchery and Baker River trap).

The use of different gears to obtain the tagging and recovery samples is a common technique for minimizing the bias due to selectivity (Ricker 1975; Seber 1982). In this study, coho salmon were captured for tagging using a beach seine. Recovery samples were either a census of all adults returning to an area (Marblemount Hatchery and Baker River trap) and thus non-selective, or were samples collected on the spawning grounds during foot surveys (and to a lesser extent by traps in some areas). We do not feel that selectivity (non-random sampling) was a significant source of bias for the estimates because: (1) the methods used to capture coho salmon for tagging were different from those used to recover them; and (2) a majority of the tag recoveries used to estimate abundance were collected by a census.

Tagging Does Not Affect the Catchability of an Animal

This assumption is necessary because some of the coho salmon passing through the tagging area were subject to an in-river commercial fishery above the tagging area. If jaw-tagged coho salmon were removed at a different rate than untagged fish, the percentage of tags in any recovery samples collected after this removal would be different from the percentage of tags in the population immediately after tagging. There is no evidence of selective removal of tagged fish in the data. In 1986, the percentage of tagged fish in commercial fishery samples from area 78D was essentially the same as that observed at Marblemount Hatchery, Baker River trap, and in samples from most upstream spawning grounds.

Animals Do Not Lose Their Tags Between the First and Second Samples

In 1986, 24% of the tagged coho salmon recovered had missing or illegible tags. How-ever, the use of opercula punches on all tagged fish allowed coho salmon with missing tags to be identified as previously tagged. Identified tag loss must be accounted for only in the Darroch estimate of abundance which requires that the release period of recovered individuals be known. When there was no tag but an operculum punch was present (or the tag was illegible), the release period was estimated as described in the Methods section. This was required only when the Darroch estimate was selected as the appropriate model. The Darroch estimate was used only for the abundance estimate produced from the commercial fishery data. The Petersen estimate was selected as the appropriate model for all other estimates including the "best" estimate. As long as all coho salmon with a missing tag are identified by an operculum punch, the Petersen estimate is not affected by the missing tags.

All Tagged Animals are Reported in the Second Sample

Because the majority of the tag recoveries used for the abundance estimates were from Marblemount Hatchery, and all coho salmon at Marblemount Hatchery were inspected twice for tags, we expect very few jaw-tagged (or marked) fish were missed. Live fish were individually inspected for tags and marks at Baker River dam. During surveys of spawning grounds, surveyors carefully inspected each carcass for an operculum punch if no tag was visible. Considering that some carcasses were in an advanced state of decay it is possible that some fish with a missing tag were not identified. In 1986, about 5% of the carcasses examined on the upriver spawning grounds (Middle Skagit sub-basin and above) could not be sampled because of their condition.

There are No Mortalities Due to Tagging

We concluded from the tagging mortality tests conducted during four of the five study years that there was no evidence of tagging mortality. These tests provided strong evidence that there was no short-term (within 48 hours) tagging mortality. The tag recovery data from the commercial fishery samples provide additional evidence that there was no delayed tagging-

induced mortality occurring from two weeks up to three months after tagging, either. The average time between tag release and recovery for the commercial fishery recoveries, 12.4 days (Table 5), was the shortest of any of the upstream recovery areas. Since the coho salmon caught in the commercial fishery are caught relatively soon after tagging, we would expect that if there is any delayed mortality caused by tagging it would cause the commercial fishery samples to have a higher percentage of tags than the samples that are taken much later, further upstream. In 1986, ρ for the commercial fishery samples was very similar to that for most of the upstream recovery areas.

CONCLUSIONS

The estimated abundance of coho salmon in 1986 was 161,926 fish with a 95% confidence interval of 143,082 to 188,325 fish. The mark-recapture estimate is for the number of coho salmon migrating through the tagging area after tagging began on 15 September. It includes all coho salmon bound for spawning areas above the tagging area and an unknown fraction of the salmon from spawning areas in the Nookachamps and Carpenter sub-basins. This abundance estimate was very precise (CV = 6.5%) because of the large number of fish examined for tags during in-sample surveys. To restrict the estimate to spawning areas in the Middle Skagit sub-basin and spawning areas above it, adjustments were made to the number of tags released. Using the adjusted number of tags released, the estimated abundance for this more restricted area was 155,889 coho salmon. The variance of this estimate was not calculated because of the unknown precision for the estimated number of tags "lost" to downstream areas. The adjusted estimate falls within the 95% confidence interval of the original estimate.

To estimate the number of "wild" coho salmon which reached upstream spawning areas in the Skagit River during 1986, the number of hatchery fish plus any catches by the commercial and test fisheries above the tagging area need to be removed from the adjusted estimate and the number of fish which migrated through the tagging area prior to tagging needs to be added. Since fish which migrated through the tagging area before tagging began are included in the spawning ground samples, only prior-migrating fish returning to Baker River and Marblemount Hatchery need to be included. Since these areas were censused, we have a total count of the prior-migrating fish to these areas: 594 fish to Baker River and 582 fish to Marblemount Hatchery. In-population sport catches should also be subtracted from the adjusted estimate. In-river catches of coho salmon by the sport fishery in the Skagit River were estimated to be only 1,819 fish in 1986 (WDF 1987) and were not included in the summary total as the specific dates and areas of harvest of these fish are unknown. A summary of the total terminal area run of coho salmon to the Skagit River in 1986 is presented in Table 7**. The total terminal area run of coho salmon to the Skagit River in 1986 is estimated to be 187,525 fish. An estimated 139,153 coho salmon were in the "wild" escapement to Skagit River spawning grounds**: 127,750 fish were estimated to have reached upstream spawning grounds and 11,403 coho salmon were estimated for lower river (Nookachamps and Carpenter sub-basin) spawning grounds. For comparison, the escapement of "wild" coho salmon to Skagit River spawning grounds estimated using index area surveys was 45,000 fish (Jeff Parkhurst, WDFW, personal communication). This estimate is two-thirds smaller than the tagging estimate. An alternative estimate, derived from CWT recoveries in the test fisheries and trap recoveries (Hayman 1996), was for a wild escapement of 60,000 to 68,000 fish (depending upon the hatchery stray rate assumed). Using a redd-count method, Conrad et al. (1993) estimated the wild escapement to be 64,000 to 96,000 fish (depending upon the number of coho salmon per redd assumed).

Table 7. Summary of the number of coho salmon returning to Skagit Bay in 1986.

Component	In-Population	Out of Population	Total
Upstream Estimated Total	155,889	1,397	157,286
Marblemount Hatchery	12,388	582	12,970
Baker River Trap Hatchery[a]	2,277	45	2,322
Area 78D Commercial Catch	13,721	0	13,721
Upstream Test Fishery Catch	523	0	523
Upstream Removals and Hatchery Fish	28,909	627	29,536
Estimated "Wild" Escapement to Upstream Spawning Areas	126,980	770	127,750
Nookachamps Sub-basin Estimated Escapement		10,306	10,306
Carpenter Sub-basin Estimated Escapement		1,097	1,097
Areas 78C, 8E, 8 Commercial Catches		16,155	16,155
Downstream Test Fishery Catch		2,681	2,681
Downstream Total		30,239	30,239
"Wild" Escapement[b] to Spawning Grounds	126,980	12,173	139,153[c]
Total Terminal Run to Skagit Bay	155,889	31,636	187,525[d]

[a] Total number of coho salmon with adipose fin clips observed at the Baker River trap. In addition, 3,575 "wild" coho salmon (fish with adipose fins) returned to the trap of which 770 returned prior to 19 September and were deemed out of population (Steve Fransen, SSC, personal communication). The wild totals are included in the "wild" escapement numbers.

[b] Includes estimated "wild" escapement to upstream spawning areas and estimated escapement to the Nookachamps and Carpenter sub-basins (from Conrad et. al 1993).

[c] The estimated catch by the in-river sport fishery was 1,819 coho salmon, but the specific dates and areas of harvest of these fish are unknown. The total wild escapement should be reduced by the number of coho salmon caught in the sport fishery in upstream areas after tagging began. The total terminal run should be increased by the number caught in downstream areas or before tagging started.

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APPENDIX A

Summary tables of sample data for 1986.

Appendix Table A-1. Summary of coho salmon escapement samples collected at Marblemount Hatchery in 1986.

Sample Date	Sample Method	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
3-Nov	Pond Mortality	25	1	4.0%
24-Nov	Spawned	1,138	10	0.9%
25-Nov	Spawned	1,418	9	1.3%
26-Nov	Pond Mortality	202	9	4.5%
	Surplused	265	6	2.3%
	Total	467	15	3.2%
1-Dec	Pond Mortality	495	15	3.0%
	Spawned	922	8	0.9%
	Total	1,417	23	1.6%
2-Dec	Spawned	1,633	13	0.8%
4-Dec	Surplused	1,728	13	0.8%
5-Dec	Pond Mortality	388	7	1.8%
8-Dec	Surplused	2,066	22	1.1%
9-Dec	Pond Mortality	179	1	0.6%
12-Dec	Surplused	525	4	0.8%
15-Dec	Pond Mortality	8	0	0.0%
	Surplused	112	0	0.0%
	Total	120	0	0.0%
22-Dec	Surplused	648	5	0.8%
29-Dec	Surplused	434	2	0.5%
7-Jan	Pond Mortality	102	0	0.0%
9-Jan	Surplused	83	1	1.2%
23-Jan	Pond Mortality	17	1	5.9%
Subtotals	Pond Mortality	1,416	34	2.4%
	Surplused	5,861	53	0.9%
	Spawned	5,111	50	1.0%
IN-SAMPLE TOTAL		12,388	137	1.1%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-2. Summary of the number of days between release in the lower Skagit River and recovery at the trap at Baker River dam for coho salmon tagged from 1986 through 1990.

Year	Average Number of Days	Standard Error	Sample Size	Range Minimum	-	Maximum
1986	27.3	2.1	43	8	-	64
1987	28.5	1.6	101	4	-	64
1988	21.4	1.6	67	5	-	85
1989	25.3	3.2	15	8	-	53
1990	23.1	2.7	15	12	-	42

Appendix Table A-3. Summary of coho salmon escapement samples collected at Baker River trap in 1986.

Sample Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
25-Aug	13	0	0.0%
8-Sep	59	0	0.0%
10-Sep	70	0	0.0%
11-Sep	181	0	0.0%
12-Sep	58	0	0.0%
16-Sep	126	0	0.0%
17-Sep	87	0	0.0%
Subtotal	594	0	0.0%
19-Sep	86	0	0.0%
23-Sep	257	0	0.0%
24-Sep	102	0	0.0%
26-Sep	78	0	0.0%
29-Sep	134	1	0.7%
1-Oct	248	1	0.4%
3-Oct	344	3	0.9%
6-Oct	160	0	0.0%
7-Oct	141	0	0.0%
10-Oct	125	0	0.0%
13-Oct	227	0	0.0%
15-Oct	287	4	1.4%
17-Oct	79	0	0.0%
20-Oct	215	2	0.9%
22-Oct	147	4	2.7%
24-Oct	70	1	1.4%
27-Oct	231	6	2.6%
28-Oct	429	7	1.6%
30-Oct	509	3	0.6%
31-Oct	255	3	1.2%
3-Nov	173	1	0.6%
7-Nov	209	0	0.0%
10-Nov	77	1	1.3%
14-Nov	92	1	1.1%
21-Nov	231	8	3.5%
26-Nov	64	1	1.6%
1-Dec	18	1	5.6%
5-Dec	3	0	0.0%
12-Dec	15	0	0.0%
19-Dec	7	0	0.0%
24-Dec	16	0	0.0%
31-Dec	7	0	0.0%
16-Jan	4	0	0.0%
23-Jan	1	0	0.0%
IN-SAMPLE TOTAL	5,041	48	1.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-4. Summary of coho salmon catch samples collected from the commercial fishery in area 78D, 1986.

Sample Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
26-Sep	2,148	14	0.7%
3-Oct	1,917	6	0.3%
Subtotal	4,065	20	0.5%
10-Oct	685	9	1.3%
18-Oct	769	13	1.7%
24-Oct	813	9	1.1%
Subtotal	2,267	31	1.4%
25-Oct	334	16	4.8%
12-Nov	160	2	1.3%
13-Nov	79	2	2.5%
Subtotal	573	20	3.5%
20-Nov	140	0	0.0%
23-Dec	281	2	0.7%
6-Jan	13	0	0.0%
Subtotal	434	2	0.5%
IN-SAMPLE TOTAL	7,339	73	1.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-5. Summary of coho salmon catch samples collected during test fisheries in the Skagit River, 1986.

Sample Date	Area 2 Number Examined	Area 2 # Tags Found[a]	Area 2 % w/Tags (ρ)	Areas 3 and 4 Number Examined	Areas 3 and 4 # Tags Found[a]	Areas 3 and 4 % w/Tags (ρ)
21-Aug						
28-Aug	11	0	0.0%			
29-Aug						
4-Sep	7	0	0.0%			
5-Sep						
Subtotal	18	0	0.0%			
18-Sep	47	0	0.0%	20	0	0.0%
19-Sep						
23-Sep	40	0	0.0%			
25-Sep						
26-Sep						
30-Sep	63	0	0.0%			
2-Oct						
3-Oct						
7-Oct	25	0	0.0%			
9-Oct						
10-Oct						
14-Oct	62	0	0.0%			
16-Oct						
17-Oct						
21-Oct	20	0	0.0%			
23-Oct						
24-Oct						
29-Oct	187	0	0.0%	503	1	0.2%
30-Oct						
7-Nov						
IN-SAMPLE TOTAL	444	0	0.0%	523	1	0.2%

- continued -

Appendix Table A-5. Summary of coho salmon catch samples collected during test fisheries in the Skagit River, 1986 (continued).

Sample Date	Spudhouse Number Examined	Spudhouse # Tags Found[a]	Spudhouse ρ	Blakes Number Examined	Blakes # Tags Found[a]	Blakes ρ	Bay and Jetty Number Examined	Bay and Jetty # Tags Found[a]	Bay and Jetty ρ
21-Aug	11	0	0.0%	20	0	0.0%	4	0	0.0%
28-Aug									
29-Aug	32	0	0.0%	13	0	0.0%	4	0	0.0%
4-Sep									
5-Sep	53	0	0.0%	66	0	0.0%	96	0	0.0%
Subtotal	96	0	0.0%	99	0	0.0%	104		0.0%
18-Sep	61	0	0.0%	52	0	0.0%	58	0	0.0%
19-Sep				85	0	0.0%	16	0	0.0%
23-Sep									
25-Sep	17	0	0.0%	58	0	0.0%	69	0	0.0%
26-Sep				106	0	0.0%	66	0	0.0%
30-Sep									
2-Oct	15	0	0.0%	94	0	0.0%	142	0	0.0%
3-Oct				81	0	0.0%	54	0	0.0%
7-Oct									
9-Oct	57	0	0.0%	48	0	0.0%	48	0	0.0%
10-Oct				101	0	0.0%	60	0	0.0%
14-Oct									
16-Oct	21	0	0.0%	56	1	1.8%	41	0	0.0%
17-Oct				44	0	0.0%	32	0	0.0%
21-Oct									
23-Oct	59	0	0.0%	91	0	0.0%	26	0	0.0%
24-Oct				138	0	0.0%	25	0	0.0%
29-Oct							30	0	0.0%
30-Oct				27	0	0.0%			
7-Nov				11	0	0.0%	4	0	0.0%
IN-SAMPLE TOTAL	230	0	0.0%	992	1	0.1%	671	0	0.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-6. Summary of coho salmon escapement samples from the Middle Skagit sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, and at the Hansen Creek trap, 1986.

	SSC SURVEYS			WDFW SURVEYS			HANSEN CREEK TRAP			SAMPLES COMBINED		
Survey Date	Number Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)
29-Oct							12	0	0.0%	12	0	0.0%
30-Oct							1	0	0.0%	1	0	0.0%
31-Oct							2	0	0.0%	2	0	0.0%
6-Nov							4	0	0.0%	4	0	0.0%
7-Nov							2	0	0.0%	2	0	0.0%
10-Nov							1	0	0.0%	1	0	0.0%
16-Nov							2	0	0.0%	2	0	0.0%
18-Nov							37	0	0.0%	37	0	0.0%
19-Nov							29	0	0.0%	29	0	0.0%
20-Nov							26	0	0.0%	26	0	0.0%
21-Nov							52	2	3.8%	52	2	3.8%
22-Nov							36	0	0.0%	36	0	0.0%
24-Nov							19	0	0.0%	19	0	0.0%
25-Nov							2	0	0.0%	2	0	0.0%
26-Nov	1	0	0.0%				10	0	0.0%	11	0	0.0%
27-Nov							17	2	11.8%	17	2	11.8%
30-Nov							25	0	0.0%	25	0	0.0%
1-Dec	2	0	0.0%				9	0	0.0%	11	0	0.0%
2-Dec							5	0	0.0%	5	0	0.0%
3-Dec	27	1	3.7%				2	0	0.0%	29	1	3.4%
4-Dec	2	0	0.0%	5	0	0.0%	1	0	0.0%	8	0	0.0%
5-Dec				9	3	33.3%	1	0	0.0%	10	3	30.0%
6-Dec							3	0	0.0%	3	0	0.0%
7-Dec							1	0	0.0%	1	0	0.0%
8-Dec	57	1	1.8%				1	0	0.0%	58	1	1.7%
11-Dec	5	0	0.0%							5	0	0.0%
12-Dec				67	0	0.0%				67	0	0.0%
14-Dec							1	0	0.0%	1	0	0.0%
15-Dec	81	1	1.2%				1	1	100.0%	82	2	2.4%
18-Dec							1	0	0.0%	1	0	0.0%
21-Dec	24	0	0.0%							24	0	0.0%
22-Dec	26	0	0.0%	74	0	0.0%				100	0	0.0%

- continued -

Appendix Table A-6. Summary of coho salmon escapement samples from the Middle Skagit sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, and at the Hansen Creek trap, 1986 (continued).

	SSC SURVEYS			WDFW SURVEYS			HANSEN CREEK TRAP			SAMPLES COMBINED		
Survey Date	Number Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)
23-Dec				36	0	0.0%				36	0	0.0%
29-Dec	7	0	0.0%							7	0	0.0%
31-Dec				26	0	0.0%				26	0	0.0%
Subtotal	232	3	1.3%	217	3	1.4%	303	5	1.7%	752	11	1.5%
6-Jan	50	1	2.0%							50	1	2.0%
7-Jan	3	0	0.0%	45	0	0.0%				48	0	0.0%
13-Jan	13	0	0.0%							13	0	0.0%
14-Jan	3	1	33.3%	154	0	0.0%				157	1	0.6%
15-Jan	4	0	0.0%							4	0	0.0%
19-Jan	55	0	0.0%							55	0	0.0%
20-Jan	3	0	0.0%	37	0	0.0%				40	0	0.0%
21-Jan				180	1	0.6%				180	1	0.6%
22-Jan	14	0	0.0%							14	0	0.0%
23-Jan	53	0	0.0%							53	0	0.0%
26-Jan	239	0	0.0%							239	0	0.0%
28-Jan	31	0	0.0%	60	1	1.7%				91	1	1.1%
29-Jan	41	1	2.4%							41	1	2.4%
2-Feb	43	0	0.0%							43	0	0.0%
6-Feb				16	0	0.0%				16	0	0.0%
Subtotal	552	3	0.5%	492	2	0.4%	0	0	0.0%	1,044	5	0.5%
IN-SAMPLE TOTAL	784	6	0.8%	709	5	0.7%	303	5	1.7%	1,796	16	0.9%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-7. Summary of coho salmon escapement samples from the Upper Skagit sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, 1986.

	SSC SURVEYS			WDFW SURVEYS			SURVEYS COMBINED		
Survey Date	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ
10-Nov	1	0	0.0%				1	0	0.0%
19-Nov	1	0	0.0%				1	0	0.0%
3-Dec	1	0	0.0%				1	0	0.0%
4-Dec	7	1	14.3%				7	1	14.3%
5-Dec	5	0	0.0%				5	0	0.0%
8-Dec				11	0	0.0%	11	0	0.0%
9-Dec	2	0	0.0%				2	0	0.0%
15-Dec				7	0	0.0%	7	0	0.0%
16-Dec	5	0	0.0%				5	0	0.0%
17-Dec	78	1	1.3%				78	1	1.3%
19-Dec	1	0	0.0%				1	0	0.0%
22-Dec	71	0	0.0%				71	0	0.0%
24-Dec	12	0	0.0%				12	0	0.0%
30-Dec	5	0	0.0%				5	0	0.0%
5-Jan	2	0	0.0%				2	0	0.0%
6-Jan	7	0	0.0%	6	0	0.0%	13	0	0.0%
7-Jan	39	0	0.0%				39	0	0.0%
8-Jan				1	0	0.0%	1	0	0.0%
9-Jan	1	0	0.0%				1	0	0.0%
11-Jan	13	0	0.0%				13	0	0.0%
12-Jan	33	0	0.0%				33	0	0.0%
16-Jan	8	0	0.0%				8	0	0.0%
17-Jan	11	0	0.0%				11	0	0.0%
19-Jan	11	0	0.0%				11	0	0.0%
22-Jan	40	0	0.0%				40	0	0.0%
23-Jan	5	0	0.0%				5	0	0.0%
27-Jan	9	1	11.1%				9	1	11.1%
28-Jan				4	0	0.0%	4	0	0.0%
29-Jan	10	0	0.0%				10	0	0.0%
30-Jan	7	0	0.0%				7	0	0.0%
2-Feb	8	0	0.0%				8	0	0.0%
3-Feb	10	0	0.0%				10	0	0.0%
9-Feb	1	0	0.0%				1	0	0.0%
10-Feb	2	0	0.0%				2	0	0.0%
12-Feb				1	0	0.0%	1	0	0.0%
19-Feb	5	0	0.0%				5	0	0.0%
26-Feb	5	0	0.0%				5	0	0.0%
IN-SAMPLE TOTAL	416	3	0.7%	30	0	0.0%	446	3	0.7%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-8. Summary of coho salmon escapement samples from the Lower Sauk sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, 1986.

	SSC SURVEYS			WDFW SURVEYS			SURVEYS COMBINED		
Survey Date	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ
26-Nov				1	0	0.0%	1	0	0.0%
11-Dec	3	0	0.0%				3	0	0.0%
12-Dec				32	0	0.0%	32	0	0.0%
17-Dec	7	0	0.0%				7	0	0.0%
23-Dec	16	0	0.0%	6	0	0.0%	22	0	0.0%
30-Dec	18	0	0.0%				18	0	0.0%
5-Jan				7	0	0.0%	7	0	0.0%
8-Jan	16	0	0.0%				16	0	0.0%
13-Jan	263	1	0.4%				263	1	0.4%
14-Jan				48	0	0.0%	48	0	0.0%
22-Jan	275	4	1.5%				275	4	1.5%
23-Jan	104	0	0.0%				104	0	0.0%
29-Jan	178	4	2.2%	28	0	0.0%	206	4	1.9%
30-Jan	51	0	0.0%				51	0	0.0%
4-Feb	67	1	1.5%				67	1	1.5%
5-Feb	43	1	2.3%				43	1	2.3%
6-Feb				10	0	0.0%	10	0	0.0%
12-Feb	54	0	0.0%				54	0	0.0%
18-Feb	4	0	0.0%				4	0	0.0%
20-Feb	20	0	0.0%				20	0	0.0%
25-Feb	1	0	0.0%				1	0	0.0%
IN-SAMPLE TOTAL	1,120	11	1.0%	132	0	0.0%	1,252	11	0.9%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-9. Summary of coho salmon escapement samples from the Middle Sauk sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, 1986.

	SSC SURVEYS			WDFW SURVEYS			SURVEYS COMBINED		
Survey Date	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ
12-Nov				1	0	0.0%	1	0	0.0%
18-Nov	2	0	0.0%				2	0	0.0%
3-Dec				22	0	0.0%	22	0	0.0%
5-Dec	67	1	1.5%				67	1	1.5%
8-Dec	24	1	4.2%				24	1	4.2%
12-Dec	58	0	0.0%	104	1	1.0%	162	1	0.6%
16-Dec	186	1	0.5%				186	1	0.5%
23-Dec				1	0	0.0%	1	0	0.0%
24-Dec	45	0	0.0%				45	0	0.0%
30-Dec	10	0	0.0%				10	0	0.0%
31-Dec	9	1	11.1%				9	1	11.1%
2-Jan				33	0	0.0%	33	0	0.0%
5-Jan	91	0	0.0%	4	0	0.0%	95	0	0.0%
9-Jan				45	0	0.0%	45	0	0.0%
12-Jan	349	0	0.0%				349	0	0.0%
15-Jan	28	0	0.0%				28	0	0.0%
16-Jan	142	1	0.7%	25	0	0.0%	167	1	0.6%
20-Jan	311	1	0.3%				311	1	0.3%
21-Jan	60	0	0.0%				60	0	0.0%
22-Jan				77	1	1.3%	77	1	1.3%
24-Jan	4	0	0.0%				4	0	0.0%
27-Jan	201	0	0.0%				201	0	0.0%
29-Jan				34	1	2.9%	34	1	2.9%
2-Feb	18	0	0.0%				18	0	0.0%
6-Feb				40	0	0.0%	40	0	0.0%
10-Feb	38	0	0.0%				38	0	0.0%
12-Feb				47	0	0.0%	47	0	0.0%
18-Feb	33	0	0.0%				33	0	0.0%
25-Feb	1	0	0.0%				1	0	0.0%
IN-SAMPLE TOTAL	1,677	6	0.4%	433	3	0.7%	2,110	9	0.4%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-10. Summary of coho salmon escapement samples from the Upper Sauk sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1986.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
25-Nov	2	0	0.0%
19-Dec	16	0	0.0%
16-Jan	18	0	0.0%
21-Jan	36	1	2.8%
22-Jan	25	0	0.0%
23-Jan	2	0	0.0%
30-Jan	25	0	0.0%
4-Feb	18	0	0.0%
10-Feb	2	0	0.0%
11-Feb	52	0	0.0%
IN-SAMPLE TOTAL	196	1	0.5%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-11. Summary of coho salmon escapement samples from the Suiattle sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1986.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
2-Dec	7	0	0.0%
10-Dec	58	0	0.0%
12-Dec	3	0	0.0%
17-Dec	38	0	0.0%
18-Dec	64	0	0.0%
23-Dec	35	0	0.0%
30-Dec	16	1	6.3%
6-Jan	70	0	0.0%
8-Jan	39	1	2.6%
9-Jan	1	0	0.0%
10-Jan	5	0	0.0%
13-Jan	135	2	1.5%
14-Jan	11	0	0.0%
20-Jan	16	0	0.0%
21-Jan	12	0	0.0%
22-Jan	106	1	0.9%
23-Jan	5	0	0.0%
28-Jan	19	0	0.0%
29-Jan	25	0	0.0%
1-Feb	16	0	0.0%
5-Feb	63	1	1.6%
7-Feb	2	0	0.0%
9-Feb	104	2	1.9%
17-Feb	65	0	0.0%
18-Feb	5	0	0.0%
19-Feb	1	0	0.0%
25-Feb	39	0	0.0%
IN-SAMPLE TOTAL	960	8	0.8%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-12. Summary of coho salmon escapement samples from the Nookachamps sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, 1986.

	SSC SURVEYS			WDFW SURVEYS			SURVEYS COMBINED		
Survey Date	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ
3-Nov	1	0	0.0%				1	0	0.0%
2-Dec	1	0	0.0%				1	0	0.0%
3-Dec	2	0	0.0%				2	0	0.0%
5-Dec	5	0	0.0%				5	0	0.0%
9-Dec	4	0	0.0%				4	0	0.0%
10-Dec	11	0	0.0%				11	0	0.0%
16-Dec	42	0	0.0%				42	0	0.0%
19-Dec	42	0	0.0%				42	0	0.0%
21-Dec	6	0	0.0%				6	0	0.0%
22-Dec	17	0	0.0%	10	0	0.0%	27	0	0.0%
23-Dec	1	0	0.0%				1	0	0.0%
31-Dec		0	0.0%	4	0	0.0%	4	0	0.0%
5-Jan	22	0	0.0%				22	0	0.0%
7-Jan		0	0.0%	7	0	0.0%	7	0	0.0%
14-Jan		0	0.0%	3	0	0.0%	3	0	0.0%
15-Jan	25	0	0.0%				25	0	0.0%
19-Jan	22	0	0.0%				22	0	0.0%
21-Jan	1	0	0.0%				1	0	0.0%
26-Jan	15	0	0.0%				15	0	0.0%
2-Feb	1	0	0.0%				1	0	0.0%
11-Feb	1	0	0.0%				1	0	0.0%
IN-SAMPLE TOTAL	219	0	0.0%	24	0	0.0%	243	0	0.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-13. Summary of coho salmon escapement samples from the Carpenter sub-basin collected during spawning ground surveys by Skagit System Cooperative crews and at the Fisher Creek trap, 1986.

	SURVEYS			FISHER CREEK TRAP			SAMPLES COMBINED		
Survey Date	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ
28-Oct	1	0	0.0%				1	0	0.0%
7-Nov				1	0	0.0%	1	0	0.0%
8-Nov				1	0	0.0%	1	0	0.0%
19-Nov				3	0	0.0%	3	0	0.0%
20-Nov				50	0	0.0%	50	0	0.0%
21-Nov				20	0	0.0%	20	0	0.0%
22-Nov				10	1	10.0%	10	1	10.0%
23-Nov				25	0	0.0%	25	0	0.0%
24-Nov				4	0	0.0%	4	0	0.0%
26-Nov				7	0	0.0%	7	0	0.0%
4-Dec	1	0	0.0%	2	0	0.0%	3	0	0.0%
5-Dec	1	0	0.0%				1	0	0.0%
11-Dec	7	1	14.3%				7	1	14.3%
15-Dec	6	0	0.0%				6	0	0.0%
22-Dec	4	0	0.0%				4	0	0.0%
24-Dec				2	0	0.0%	2	0	0.0%
27-Dec				1	0	0.0%	1	0	0.0%
29-Dec				9	0	0.0%	9	0	0.0%
30-Dec				1	0	0.0%	1	0	0.0%
31-Dec				2	0	0.0%	2	0	0.0%
5-Jan	1	0	0.0%				1	0	0.0%
6-Jan	8	0	0.0%				8	0	0.0%
15-Jan	1	0	0.0%				1	0	0.0%
IN-SAMPLE TOTAL	30	1	3.3%	138	1	0.7%	168	2	1.2%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-14. Summary of coho salmon escapement samples from the Cascade sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1986.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
19-Sep	1	0	0.0%
13-Nov	7	0	0.0%
26-Nov	3	0	0.0%
3-Dec	9	0	0.0%
9-Dec	19	0	0.0%
11-Dec	50	0	0.0%
15-Dec	8	0	0.0%
16-Dec	13	0	0.0%
18-Dec	43	0	0.0%
22-Dec	32	0	0.0%
29-Dec	13	0	0.0%
30-Dec	4	0	0.0%
6-Jan	5	0	0.0%
7-Jan	1	0	0.0%
8-Jan	12	0	0.0%
16-Jan	5	0	0.0%
18-Jan	9	0	0.0%
19-Jan	7	0	0.0%
30-Jan	1	0	0.0%
12-Feb	1	0	0.0%
IN-SAMPLE TOTAL	243	0	0.0%

[a] Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

Appendix Table A-15. CPUE (catch per beach seine set) of coho salmon bound for major recovery areas in the Skagit River, 1986. CPUE for recovery areas estimated using in-sample tag recoveries.

Recoveries by release strata.

Tag Release Period	Number of Sets	Coho Catch	Catch/ Set	MM Hatchery	Baker R. Trap	Middle Skagit
1. 01-Sep to 10-Sep	0	0		0	0	0
2. 11-Sep to 20-Sep	40	131	3.3	4	6	0
3. 21-Sep to 30-Sep	63	435	6.9	28	21	3
4. 01-Oct to 10-Oct	44	173	3.9	6	5	0
5. 11-Oct to 20-Oct	58	516	8.9	29	9	3
6. 21-Oct to 30-Oct	50	347	6.9	16	1	1
7. 31-Oct to 09-Nov	27	146	5.4	4	1	4
8. 10-Nov to 19-Nov	11	13	1.2	1	0	0
9. 20-Nov to 29-Nov	0	0		0	0	0
10. 30-Nov to 09-Dec	0	0		0	0	0
Totals	293	1,761	6.0	88	43	11

CPUE of fish bound for indicated recovery areas.

Release Period	MM Hatchery	Baker R. Trap	Middle Skagit
1	0.00	0.00	0.00
2	0.10	0.15	0.00
3	0.44	0.33	0.05
4	0.14	0.11	0.00
5	0.50	0.16	0.05
6	0.32	0.02	0.02
7	0.15	0.04	0.15
8	0.09	0.00	0.00
9	0.00	0.00	0.00
10	0.00	0.00	0.00
Totals	1.74	0.81	0.27

CPUE standardized as a percentage of total for area.

Release Period	MM Hatchery	Baker R. Trap	Middle Skagit
1	0.0%	0.0%	0.0%
2	5.7%	18.5%	0.0%
3	25.5%	41.2%	17.8%
4	7.8%	14.0%	0.0%
5	28.7%	19.2%	19.3%
6	18.4%	2.5%	7.5%
7	8.5%	4.6%	55.4%
8	5.2%	0.0%	0.0%
9	0.0%	0.0%	0.0%
10	0.0%	0.0%	0.0%
Totals	100.0%	100.0%	100.0%

Appendix Table A-16. Summary of the number of tag releases and number of in-sample tag recoveries by length for male and female coho salmon tagged in the lower Skagit River, 1986.

	MALES			FEMALES		
Length in cm	Number Released	Number Recovered	Percent Recovered	Number Released	Number Recovered	Percent Recovered
≤ 35	26	0	0.0%	2	0	0.0%
36	4	0	0.0%	1	0	0.0%
37	5	0	0.0%	1	1	100.0%
38	10	2	20.0%	1	0	0.0%
39	13	0	0.0%	1	0	0.0%
40	17	0	0.0%	3	0	0.0%
41	19	2	10.5%	3	0	0.0%
42	20	0	0.0%	6	2	33.3%
43	38	2	5.3%	12	1	8.3%
44	47	3	6.4%	19	2	10.5%
45	38	2	5.3%	13	0	0.0%
46	30	3	10.0%	14	2	14.3%
47	42	5	11.9%	13	1	7.7%
48	42	3	7.1%	27	6	22.2%
Subtotal	351	22	6.3%			
49	66	8	12.1%	15	4	26.7%
50	45	4	8.9%	26	3	11.5%
51	51	8	15.7%	33	8	24.2%
52	50	5	10.0%	33	5	15.2%
Subtotal	212	25	11.8%	223	35	15.7%
53	52	9	17.3%	49	8	16.3%
54	40	8	20.0%	46	8	17.4%
55	40	4	10.0%	44	8	18.2%
56	36	4	11.1%	46	9	19.6%
57	24	5	20.8%	43	5	11.6%
58	34	10	29.4%	44	6	13.6%
59	31	10	32.3%	47	6	12.8%
60	34	6	17.6%	40	5	12.5%
61	16	5	31.3%	40	6	15.0%
62	16	2	12.5%	30	2	6.7%
63	18	5	27.8%	25	5	24.0%
64	10	2	20.0%	20	3	15.0%
65	8	0	0.0%	11	1	9.1%
66	7	1	14.3%	10	1	10.0%
67	5	2	40.0%	5	1	20.0%
68	3	0	0.0%	4	0	0.0%
69	3	1	33.3%	8	3	37.5%
70	2	1	50.0%	2	0	0.0%
71	2	0	0.0%	1	0	0.0%
72	0	0	0.0%	1	0	0.0%
73	1	0	0.0%	2	0	0.0%
74	0	0	0.0%	0	0	0.0%
75	1	1	100.0%	0	0	0.0%
76	1	0	0.0%	0	0	0.0%
77	0	0	0.0%	0	0	0.0%
78	0	0	0.0%	0	0	0.0%
79	1	1	100.0%	0	0	0.0%
Subtotal	385	77	20.0%	518	78	15.1%
TOTAL	948	124	13.1%	741	113	15.3%

Appendix Table A-17. Daily summary of the numbers of coho salmon tagged in the lower Skagit River and recovered during in-sample surveys, by sex, release condition, and maturity classification, 1986.

	SEX				CONDITION						MATURITY					
	Male		Female		x-		x		x+		Bright		Blush		Dark	
Date	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.
15-Sep	21	3	12	0	0	0	5	0	28	3	33	3	0	0	0	0
16-Sep	19	5	17	6	0	0	13	3	23	8	35	11	1	0	0	0
17-Sep	4	1	1	0	0	0	0	0	5	1	3	0	2	1	0	0
18-Sep	37	6	20	4	0	0	7	0	50	10	57	10	0	0	0	0
22-Sep	22	5	29	5	2	1	34	6	15	3	47	10	4	0	0	0
23-Sep	43	6	35	5	0	0	8	1	70	10	72	11	6	0	0	0
24-Sep	73	17	32	6	0	0	93	20	12	3	97	21	8	2	0	0
29-Sep	73	13	42	8	0	0	105	18	10	3	107	18	8	3	0	0
30-Sep	58	9	28	3	3	0	2	0	81	12	86	12	0	0	0	0
1-Oct	9	1	12	2	0	0	3	0	18	3	21	3	0	0	0	0
6-Oct	63	6	62	12	14	2	111	16	0	0	98	15	27	3	0	0
7-Oct	8	0	9	2	1	0	16	2	0	0	10	1	7	1	0	0
8-Oct	7	0	3	0	2	0	8	0	0	0	8	0	1	0	0	0
13-Oct	111	12	59	8	9	0	161	20	0	0	57	8	113	12	0	0
14-Oct	11	2	15	6	4	2	22	6	0	0	10	3	16	5	0	0
15-Oct	91	14	99	17	8	0	182	31	0	0	113	21	77	10	0	0
20-Oct	62	5	64	6	3	1	122	10	1	0	47	4	78	7	0	0
21-Oct	40	2	17	3	2	0	55	5	0	0	13	3	40	2	4	0
22-Oct	10	2	10	1	0	0	20	3	0	0	9	0	10	3	1	0
28-Oct	79	6	62	3	12	1	129	8	0	0	47	1	85	8	9	0
29-Oct	38	1	44	6	10	1	72	6	0	0	44	2	33	5	5	0
30-Oct	14	0	12	2	6	0	20	2	0	0	15	2	8	0	3	0
31-Oct	9	2	10	1	5	1	14	2	0	0	10	0	8	2	1	1
4-Nov	0	0	2	0	1	0	1	0	0	0	1	0	1	0	0	0
5-Nov	39	6	39	6	5	0	72	12	1	0	33	4	43	7	2	1
14-Nov	7	0	6	1	0	0	13	1	0	0	1	0	12	1	0	0
TOTAL	948	124	741	113	87	9	1,288	172	314	56	1,074	163	588	72	25	2
% Recovered		13.1		15.3		10.3		13.4		17.8		15.2		12.2		8.0

Appendix Table A-18. Summary of the estimated number of tags from areas downstream of the tagging area in the lower Skagit River, 1986.

A. Downstream commercial fishery and test fishery catches.

Area	Catch[a] Before Tagging	Catch After Tagging	Number of Fish Examined	Number of Tags Found	Estimated Total Tags Present
8E	0	771	0		
8	122	3,329	0		
78C	558	11,375	0		
Test Fishery[b]	317	2,364	2,337	1	
Total	997	17,839	2,337	1	7.6

[a] Catches prior to tagging not included in tag recovery expansions.

[b] Test fisheries at Area 2, Spudhouse, Blakes, Bay, and Jetty.

B. Downstream spawning areas (redd data from Conrad et al. [1993]).

Area	Estimated Number of Redds	Estimated Number of Fish/Redd	Estimated Total Escapement	Number of Fish Examined	Number of Tags Found	Estimated Total Tags Present
Carpenter	211	5.2	1,097	168	2	
Nookachamps	1,982	5.2	10,306	243	0	
Total	2,193	5.2	11,403	411	2	55.5

APPENDIX B

Details of abundance estimates generated for 1986.

APPENDIX B

RECOVERY LOCATION: Marblemount Hatchery

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,689
Number of Fish Examined for Tags = 12,388
Number of Tagged or Marked Fish Recovered = 137

RECOVERY LOCATION: Baker River Trap

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,689
Number of Fish Examined for Tags = 5,041
Number of Tagged or Marked Fish Recovered = 48

RECOVERY LOCATION: Marblemount-Baker Pooled

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,689
Number of Fish Examined for Tags = 17,429
Number of Tagged or Marked Fish Recovered = 185

APPENDIX B

RECOVERY LOCATION: Lower Sauk Sub-basin

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,689
Number of Fish Examined for Tags = 1,252
Number of Tagged or Marked Fish Recovered = 11

RECOVERY LOCATION: Middle Sauk Sub-basin

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 1,689
Number of Fish Examined for Tags = 2,110
Number of Tagged or Marked Fish Recovered = 9

RECOVERY LOCATION: Suiattle Sub-basin

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:

Number of Tags Released = 1,689
Number of Fish Examined for Tags = 960
Number of Tagged or Marked Fish Recovered = 8

APPENDIX B

RECOVERY LOCATION: Lower Sauk-Middle Sauk-Suiattle Pooled

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:

Number of Tags Released = 1,689
Number of Fish Examined for Tags = 4,322
Number of Tagged or Marked Fish Recovered = 28

RECOVERY LOCATION: Marblemount-Baker-Lower Sauk-Suiattle Pooled

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:

Number of Tags Released = 1,689
Number of Fish Examined for Tags = 19,641
Number of Tagged or Marked Fish Recovered = 204

RECOVERY LOCATION: Commercial Fishery

ESTIMATION METHOD: Darroch

TAG RELEASE AND RECOVERY SUMMARY:

RELEASE STRATA	RECOVERY STRATA					Number Not Recovered	Number Tagged	Percent Recovered
	26-Sep to 3-Oct	10-Oct to 24-Oct	25-Oct to 13-Nov	20-Nov to 23-Dec	Total			
15 Sep - 24 Sep	17	5	3	0	25	340	365	6.8%
29 Sep - 8 Oct	3	13	1	0	17	357	374	4.5%
13 Oct - 22 Oct	0	13	14	0	27	562	589	4.6%
28 Oct - 2 Nov	0	0	2	2	4	357	361	1.1%
Number Tagged	20	31	20	2	73	1,616	1,689	4.3%
Number Untagged	4,045	2,236	553	419	7,253			
Number Examined	4,065	2,267	573	421	7,326			
Percent Tagged	0.5%	1.4%	3.5%	0.5%	1.0%			

APPENDIX B